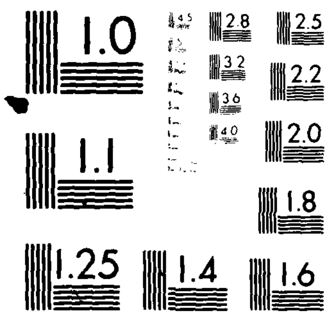
AD-A107 258 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH F/G 6/5
LONG AND SHORT-TERM MEMORY PROCESSES IN CORTICALLY DAMAGED PATI--ETC(U)
1981 J GRAFMAN
UNCLASSIFIED AFIT-CI-81-54D NL

1 of 2
AD
A107258



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 81-54D	2. GOVT ACCESSION NO. AD A107 258	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Long and Short-Term Memory Processes in Cortically Damaged Patients.		5. TYPE OF REPORT & PERIOD COVERED ~~THESIS~~/DISSERTATION
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jordan Grafman		8. CONTRACT OR GRANT NUMBER(s) Doctoral thesis
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: University of Wisconsin-Madison		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433		12. REPORT DATE 1981
		13. NUMBER OF PAGES 148 173
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) LEVEL		15. SECURITY CLASS. (of this report) UNCLASS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

AFIT-CI-81-54D

DTIC ELECTE NOV 6 1981 S D H

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

16 OCT 1981

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17

Fredric C. Lynch

FREDRIC C. LYNCH, Major, USAF
Director of Public Affairs
Air Force Institute of Technology (ATC)
Wright-Patterson AFB, OH 45433

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED

81 10 27 254

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When

AD A107258

DTIC FILE COPY

ABSTRACT

The purpose of this study was to examine the contribution of the cerebral (non-limbic) cortex to specific verbal memory processes. Based on a literature review of psycholinguistic and memory processes in normals and central nervous system impaired patients, a tentative model of the brain regions subserving verbal memory processes was developed by the author. The model suggests that the left hemispheric cortex subserves both short term memory and lexical/conceptual storage, while the encoding or "tagging" process that results in verbal information being transformed from a short term to long term state is dependent upon subcortical (limbic-thalamic) systems. In this model, the right hemispheric cortex is only minimally involved in verbal memory, contributing imaginal processing capabilities to rehearsal and retrieval of verbal information from a lexicon located in the right temporal-parietal cortex.

To test the validity of this model, several hypotheses were developed. It was suggested that left cortically lesioned patients would have an inferior performance to controls and right cortically lesioned patients on recall, retrieval from long term storage, and long term storage measures on early trials of a Selective Reminding Test primarily due to a phonemic processing impairment. It was also suggested that only cortically lesioned patients (but not controls) would have poorer recall for low frequency relative to high frequency

words. Finally it was postulated that the left cortically lesioned group would have a significantly inferior stimulus discrimination (d') score on a Word Recognition Test signifying impaired verbal stimulus discriminability due to impaired phonemic processing capability. Other hypotheses regarding the effects of cortical lesions upon word fluency and whether the left cortically lesioned patients' cognitive deficit was limited to verbal tasks were also tested.

Subjects included 18 control, 18 left cortically lesioned patients, and 18 right cortically lesioned patients matched for age and education. No cortically lesioned patient had radiological evidence of a limbic-thalamic-lesion. Patients were of normal intelligence, did not present with a clinical dysphasia, and were seen at least one-month following receipt of the neurological diagnosis assigned each patient. An additional group of 6 Korsakoff patients with presumed subcortical pathology was included for qualitative contrasts with the cortically lesioned groups.

The results suggested that the left cortically lesioned group had a limited auditory-verbal memory deficit due to both linguistic (phonemic processing) and memorial (long term retrieval) factors. Their performance, however, was both qualitatively and quantitatively superior to Korsakoff patients who demonstrated severely impaired encoding and retrieval processes as a probable result of minimal contextual or episodic tagging of verbal stimuli. The right cortically lesioned patients had a slightly depressed verbal memory performance which was attributed primarily to a nonmemorial factor (inattention), although a semantic/imaginal processing deficit was also thought to be present in these patients. There was no significant word frequency-group interaction. The right cortically lesioned group had a nonsignificantly inferior performance compared to the controls and left cortically lesioned group on a visual-spatial memory task. These findings both support and expand the model of verbal memory developed by the author and are compatible with several contemporary neuropsychological models of memory.

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to ascertain the value and/or contribution of research accomplished by students or faculty of the Air Force Institute of Technology (ATC). It would be greatly appreciated if you would complete the following questionnaire and return it to:

AFIT/NR
Wright-Patterson AFB OH 45433

RESEARCH TITLE: Long and Short-Term Memory Processes in Cortically Damaged Patients

AUTHOR: Jordan Grafman

RESEARCH ASSESSMENT QUESTIONS:

1. Did this research contribute to a current Air Force project?

( ) a. YES ( ) b. NO

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not?

( ) a. YES ( ) b. NO

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency achieved/received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

( ) a. MAN-YEARS ________ ( ) b. $________

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3. above), what is your estimate of its significance?

( ) a. HIGHLY SIGNIFICANT ( ) b. SIGNIFICANT ( ) c. SLIGHTLY SIGNIFICANT ( ) d. OF NO SIGNIFICANCE

5. AFIT welcomes any further comments you may have on the above questions, or any additional details concerning the current application, future potential, or other value of this research. Please use the bottom part of this questionnaire for your statement(s).

NAME GRADE POSITION

ORGANIZATION LOCATION

STATEMENT(s):

FOLD DOWN ON OUTSIDE - SEAL WITH TAPE

AFIT/NR
WRIGHT-PATTERSON AFB OH 45433

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 73236 WASHINGTON D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

AFIT/ DAA
Wright-Patterson AFB OH 45433

FOLD IN

LONG AND SHORT-TERM MEMORY PROCESSES IN CORTICALLY DAMAGED PATIENTS

BY

JORDAN GRAFMAN

A dissertation submitted in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

(HUMAN NEUROPSYCHOLOGY)

at the

UNIVERSITY OF WISCONSIN-MADISON

1981

PREFACE

The research which comprises the dissertation was made possible by a United States Air Force Health Professions Scholarship Award to the author and by the generous support of the members of his dissertation committee: Charles G. Matthews, Ph.D., Arthur Glenberg, Ph.D., Loren Chapman, Ph.D., Robert Davidson, Ph.D., and Charles Cleeland, Ph.D. I would also like to thank Dr. Robert Kraut, Department of Rehabitation Medicine, Madison General Hospital; Dr. Gastone Celesia, Chief of Neurology, W. H. Middleton Veteran's Administration Hospital; and Dr. William Boutelle, Chief of Psychiatry, Northampton Veteran's Administration Hospital for kindly referring their patients to me. As for the patients, each volunteered two hours time for a study that had no obvious rewards for them. They were all courteous, interested in my ideas, and eager to participate. I humbly appreciate their time and effort. Finally, and perhaps most important, I would like to thank my mother, Mrs. Phyllis Grafman, for the courage and support she showed in helping me weather the storm of my adolescent years.

This study is an initial attempt to discover and model the brain mechanisms subserving human memory. I expect this attempt will lead to a life-long pursuit. The purpose of the present research was not merely to offer another of the countless theories of cognitive processes, but to construct a model of memory that will eventually allow scientists and clinicians to become more adept at evaluating and treating memory deficits in the patient with brain dysfunction. It is to those patients that I dedicate this work.

TABLE OF CONTENTS

TABLE OF FIGURES

PAGE

INTRODUCTION

Within the last two decades there has been a growing research interest in the neuropsychological mechanisms of memory in man. This endeavor to blend brain function and human behavior is not unique to memory. Yet memory, as a major cognitive process, has not received the attention of neuropsychological investigators until relatively recently when compared with language and perception. Due to the infancy of this research pursuit, there has evolved a restricted approach towards uncovering the various components and structure of memory in the brain. That is, the overwhelming majority of published research on neuropsychological aspects of memory has been on brain-injured men and women with predominantly subcortical pathology (i.e., Korsakoff's disease), epilepsy (i.e., temporal lobectomized patients), and diffuse brain injury (i.e., closed or open wound head injuries). This line of research assumes that those cerebral regions most critical to memory processes are contained in the limbic system (i.e., mediodorsal thalamus, mammillary bodies and hippocampus). It will be the purpose of this dissertation to examine the contributions of the cerebral (non-limbic) cortex to specific verbal memory processes. An argument will be developed to support the theory that memory storage for "complex" information is differentially located in the cortex, and that subcortical and medial temporal structures probably provide for a tagging of comprehended information that then allows for vivid (i.e., easily retrievable) mnemonic representations to be stored. It will be proposed that asymmetric and specialized focal regions of the cerebral cortex process and store different aspects of a stimulus, so that memory, like language and visual-spatial perception, can be differentially affected by restricted lesions. The experimental design that is proposed below will be the first step in systematically testing and documenting the above hypotheses. The results should have significant import upon present neuropsychological theories of memory.

The review that follows is an attempt to describe recent trends in cognitive and neuropsychological theory. This review (where applicable) provides support for the simple model of memory processing in the brain that is described in Chapter 3. It will be apparent that the review introduces much more material and theory than is contained in the model as presently formulated. The purpose of the review is to impress upon the reader the varied and complex processes of verbal communication and memory that must be accounted for in any model, that the components of the model are derived from exceedingly complex brain-behavior interactions, and that neuropsychological research is both compatible with, and can supplement, classical cognitive psychological investigation.

In order to assist the reader in ascertaining the review-model relationships, a brief summary of the model is presented below. In addition, there will be comments preceding each chapter identifying its relationship to the model.

Synopsis of the Model

The model presented in Chapter 3 proposes that the left hemispheric cortex subserves both short term memory and lexical storage while the encoding or "tagging" process that results in verbal information being transformed from a short term to long term state is dependent upon subcortical (i.e., limbic/hippocampal/hypothalamic) systems. The left hemispheric cortex also subserves the articulatory and verbal mediation strategies that assist in the recallability and recognition of information in long term store.

The right hemispheric cortex is only minimally involved in verbal memory and rehearsal, contributing imaginal processing capabilities to rehearsal and retrieval of information from a visual lexicon located in the right hemisphere.

The evidence for this model and a detailed description of its components is contained in the review that follows. Studies of both normal and abnormal populations will be presented. Since both storage (psycholinguistic) and memory processes have a place in the model, both memorial and psycholinguistic research will be cited. Finally, neuropsychological research will be criticized for a lack of breadth, i.e., neuropsychological models of memory are based on results gathered from limited and rare (in number) pathological populations (e.g., Korsakoff patients).

I. PSYCHOLINGUISTICS AND NEUROLINGUISTICS

This chapter will attempt to specify both the structure of the lexicon and the processes involved in language comprehension and expression (including studies with normal and abnormal populations). This attempt to determine the properties of the lexicon may offer clues as to why certain words are more easily encoded and recalled/recognized. The analysis of linguistic processes should reveal the various components of language processing that enable humans to express or comprehend speech sounds and attach meaning to them. The examination of neurolinguistic research (and aphasic deficits) will reveal relatively independent language processing deficits that are associated with the location and extent of brain lesions. These language deficits must be taken into account when conceptualizing lexical properties (i.e., the properties of semantic memory) or hypothesizing about "necessary" language processing steps. In addition, the description of aphasic deficits may help explain the memory disorder seen in some patients with cortical lesions. The model that is presented in Chapter 3 will (in general terms) attempt to place the lexicon and language processing components (discussed in this chapter) in relation to both cortical brain structures and memory systems.

a. Psycholinguistics

Requiring a subject to remember word lists is a standard experimental memory task that will be utilized in this dissertation.

In order to study and understand how subjects remember word lists, it is necessary first to formalize a psycholinguistic model of word storage, mediation and recall/recognition. Marshall (1976) considers a "word" to have at least three codes for representation in a language system: the orthographic, the phonological and the lexical. The orthographic and phonological representations of a "word" are derived from the intent to understand and/or express meaning. This meaning relies on access to a learned lexicon. In the lexicon, each word may be represented by a number of dictionary-like entries. In this context, studies of lexical access have been very informative, particularly in regards to the empirical formulation of models of word storage and organization.

Most of the following work has been done using a forced visual choice reaction time task. This task requires the subject to choose whether a letter string shown on a screen is a word or not (i.e., BRNVD vs. BRAND), as quickly as he can. Frederickson (1971) and others have reported decreased reaction time for correct responses to such variables as high (opposed to low) frequency, orthographic typicality, and increasing number of dictionary entries. Undoubtedly, other variables also enter into this complex matrix of decision and response time. These variables could include imagery value (Pavio, 1971), semantic differential (Osgood, 1963) and context (Foss and Blank, 1980).

If based on this evidence one can accept the concept of a lexicon, then it becomes necessary to explain the internal and external structure of this system. Models of word storage are quite numerous in contemporary human information processing research. The most experimentally productive approach began with Collins and Quillian (1969, 1971). They suggested that the items stored in semantic memory are connected by links in a huge network structure. The items in this structure are hierarchically organized into logically nested subordinate-superordinate relations. For example, the superordinate of canary is bird, and the superordinate of bird is animal. A property that characterizes all birds is stored only at bird.

Since this semantic hierarchy did not allow for typicality of category membership, Smith, Shoben and Rips (1974) proposed a feature-comparison model. They assume that the meaning (i.e., concept) of any item in memory can be represented as a set of semantic features. There are those features which are essential aspects of the item's meaning. These are called defining features. Other features do not form part of the item's definition, but are nonetheless descriptive of the items. They are referred to as characteristic features. An inherent difficulty with this model is that there is no feature that is absolutely necessary to define the distinction between defining and characteristic features (Glass and Holyoak, 1975). The model also has difficulty accounting for subjects who can disconfirm a false statement such as "some chairs are tables" faster than a statement such as "some chairs are rocks" even though chairs and tables are more similar to each other than chairs and rocks. Nevertheless, the existence of typicality of features implies a continuum of characterizing features of objects and actions even within the same conceptual category.

Lakoff (1973) has discussed linguistic devices called hedges to indicate degree of class membership. The meaning of hedges cannot be understood unless category membership is considered to be a matter of degree rather than all or none. Rosch (1973) has provided empirical evidence for these claims. She showed that natural categories, both perceptual and conceptual, are defined only ambiguously by typical member, and that various degrees of category membership do exist. In one experiment, Rosch asked subjects to rank category members as to their degree of category membership. Subjects agreed with one another quite well. For example, for the category birds, Rosch's subjects named robin and eagle as most typical, chickens and ducks as less typical. Penguins were considered marginal cases, and bats hardly as birds at all. For vegetables, carrots and asparagus were considered to be typical class members, parsley or pickle as peripheral members. These ratings are important in that they predict how well subjects can operate with the concepts involved. If subjects in a standard concept identification experiment are given sets of typical category instances to discriminate, they learn much faster than when the categories are compared with marginal category members. Learning rates directly reflect the degree of category membership.

Assigning features to words and placing those words within a logical structure does not assume clearly defined linguistic performance. That is, semantic categories are not like well defined mathematical sets, but are inherently "fuzzy". Particular aspects of words can be made more salient depending on the context in which the words are presented. Anderson and Ortney (1975) found that appliance was a very good recall cue for the sentence "television sets need expert repairmen", while for the sentence "television sets look nice in a family room", the best recall cue was furniture. Clearly both appliance and furniture are potential features of television set, but which of these learned features is activated and stored in memory depends on context. In free recall word list tasks, the context may be provided by an external structure (i.e., experimental instructions), by the relatedness of various words in the list-either inter- or intra-categorically, or the structure may be internal; that is, the subject imposes structure on the word list. In the forthcoming discussion of encoding strategies for recall and recognition, the special importance placed on initial encoding procedures and the dependence of recall accuracy upon them will be noted.

Free recall tasks initially require the subject to store a representation of the word list. When there is not some inherent structural relationship (i.e., semantic, phonemic, etc.) among the individual words, it remains for the subject to decide whether or not to utilize an encoding (as well as decoding) strategy.

How is the lexicon accessed? If we accept the proposition that the lexicon consists of fuzzy categories, what is the "pointer" that allows for basic word retrieval/recognition? Words are recognized significantly faster than non-words in a visual lexical decision task (Frederickson, 1971). Given certain constraints (i.e., nature of the auditory environment and the auditory neural processing system), does the same hold true for auditory as well as visual recognition? In fact, data reported by Broadbent (1967) indicates that it does.

He presented high and low frequency words masked by noise. Subjects were asked to write down whatever word they thought they heard even if they were unsure about it. When guessing is covaried (Morton, 1979a), the data reveals a "high frequency" advantage for word recognition. Words that appear with high frequency in the language are most easily recognized. Thus, the results for both visual and verbal presentation of words and non-words indicate that the word recognition system is biased towards particular word attributes. The evidence above supports a word frequency effect. In fact, recent research (Massaro et al., 1980) postulates word frequency, bi-gram frequency, number of dictionary entries, as well as number of meaning clusters (i.e., entries within a meaning of which a word may have one or more) as important variables.

Although it has not yet been sufficiently tested, there is no reason to presuppose that rated imagery, concreteness and abstractness would not also affect a person's ability to recall and later recognize a word. It could be that all of the following salient characteristics of words: frequency, number of lexical entries, imagery, concreteness, abstractness and the like, would interact. Those words with high frequency, large numbers of lexical entries, which are highly imagable and concrete and with low-rated abstractness, would be easiest to recognize and retrieve. The above cited research describes the lexicon in its most passive sense. When the lexicon is activated through a search procedure such as recall; the particular retrieval process used must necessarily obviate further semantic fuzziness in order to accurately recall a specific item.

The retrieval model that the author finds most parsimonious in explaining the effects of word characteristics is one formulated by Morton (1964, 1969a, 1969b, 1970, 1979a, and 1979b). Morton postulates the existence of the logogen (from logos-word, and genus-birth). The logogen is not a word itself but is the device (i.e., the pointer) which makes a word available as a response and it does so by collecting evidence that the word is or was present as a stimulus, appropriate as a response, or both. The stimulus for the presence of a particular word can come from the outside world by vision or hearing, or from other processes in the brain such as those concerned with context. The evidence can consist of physical (features), grammatical (word type), or semantic attributes. When a logogen has collected sufficient evidence, the appropriate response is made available. The amount of evidence necessary for this is called the "threshold of the logogen". The presence of a context means that less information is required from a particular stimulus for the word to be recognized. Stimulus and context information combine directly to produce a response.

In Morton's model, the simplest way of accounting for the word frequency effect is to say that the threshold of a logogen is permanently reduced by some small amount every time the logogen is active, regardless of whether the word is spoken, seen, heard, written, or merely thought. It is important to note each logogen is appropriate for only one word (and possibly non-words or letter strings depending on the analyzable unit, i.e., morphemes, single letters, etc.). The logogen is thought to operate directly on a phonological (or graphic) representation. The speech production system for words or sentences is generated by correspondence (i.e., syntactic) rules within the lexicon. Naturally, the facilitation proposal could just as easily be accounted for by surround inhibition (see Marslen-Wilson and Welch, 1978), but the logogen model remains one of the most developed models of words recognition with testable hypotheses.

PROCESSING STEPS

To this point a tentative model representation of the lexicon has been presented along with a hypothesis as to how it may be activated (logogen). This representation can be placed within the context of a simple hypothesized information processing model of language. Its compatibility with neuropsychological findings will be documented later in the review.

Sensory information (in our case, words comprising a word list) is first processed through a sensory information store (visual-iconic and/or auditory-echoic; see Crowder, 1976). This "store" is responsible for the brief storage and transfer of this information. Following the transduction of environmental stimuli to informational coding in the retina or cochlea, the extraction and analysis of critical features is carried out at higher levels in the nervous system (Luria, 1976). The output of the feature analyzers feed into a pattern synthesizer (logogen). This device uses the constraints imposed by the extracted features' contextual information (semantic, syntactic, and other), and memorial information (lexicon), to reconstruct an abstracted image of the sensory input. It is at this point where contextual, semantic and grammatical rules are instantiated, that an internal memory representation of language begins to interact with basic featural extraction.

b. Neurolinguistics

The development of neuropsychological models of language and brain function began in the sixth, seventh and eighth decades of the 19th century. Broca's and Wernicke's autopsy-correlated findings of particular kinds of language disturbances following "localizable" brain lesions spurred neurologists of the time to analyze in a careful and systematic fashion language deficits following central nervous system insult. Over a century has passed since those original reports, and since that time, behavioral scientists' clinical and experimental methods have detailed more precisely the syntactic, lexical and semantic errors that are often present in brain damaged adults (Lesser, 1978). In addition, many of the earlier claims, both from localizationist and mass action proponents regarding behavioral-brain relationships have been revised as a consequence of the sophisticated and parallel growth that has occurred in the science of psycholinguistics and human information processing.

Several generalizations appear valid in demonstrating cortical, subcortical, and hemispheric contributions to particular modes of information processing. It appears that the left hemisphere of the brain is "dominant" for verbal-linguistic cognitive strategies (Milner, 1974). The right hemisphere of the brain is dominant for visual-spatial "whole feature" analysis (Joynt and Goldstein, 1975).

These systems appear to extend subcortically in their respective hemispheres. They interact via trans and intra-callosal inhibitions and excitements (Geschwind, 1965). The behavioral opportunities to observe these interactions are biased. That is, the brain systems for expressive speech reside in the left hemisphere with rare exceptions (Hecaen and Albert, 1978). The right hemisphere maintains the brain systems that are biased for environmental exploration (e.g., route finding) and for cognitive processes that are resistant to verbal identification: matching brief exposures of unfamiliar faces as an example (Walsh, 1978). This synopsis of hemispheric functions suggests that if an investigation intends to explore verbal-linguistic memory, left-brain damaged individuals may be suitable subjects. Later on evidence will be presented that shows right hemisphere contributions to language processing.

LANGUAGE COMPREHENSION

The ability of people to comprehend language depends in great part on a number of anatomical and linguistic steps that represent hierarchical levels of cognitive processing. Efron (1963) noted the inability of several patients with left temporal lobe disease to sequence non-linguistic auditory information (tones) and suggested that the (essential deficit and) basic function of the left hemisphere was to interpret information in time and (necessarily coexisting) discrete steps. Luria (1966) describes the normal process of categorical (or phonemic) selection as being relatively automatized, based on discriminative processes, and which when disrupted can result in an acoustic aphasia. Patients with this kind of aphasia lose the normal understanding of word comprehension and meaning, but they are able to preserve the understanding of the intonational units of fluent speech. This type of aphasia is also known as Wernicke's aphasia. The typical Wernicke's patient remains fluent, but is generally restricted to jargon in speech. These patients may be evaluated by recording their performance on word discrimination tasks, to commands, to identification demands, on matching tasks, on forced choice recognition tasks, on completion tasks, etc.

PHONOLOGICAL ASPECTS OF COMPREHENSION

Despite Luria's claims of phonemic impairment in Wernicke-type aphasics, Blumstein et al. (1977) have found phoneme discrimination tasks no more difficult for the Wernicke's patient than for the anterior aphasic (Broca's or mixed types). In addition, only when whole word discriminations (that are based on phonemic and distinctive feature contrasts) are required do phonemic errors become apparent (such as errors of place). Thus, the left temporal-parietal regions may be considered to subserve two processes. The first appears to be a perceptual process responsible for phonemic discrimination. The second is a more linguistic or semantic pointer process involved in relating speech sounds to semantic meaning.

SEMANTIC AND SYNTACTIC ASPECTS OF COMPREHENSION

Patients with semantic and/or syntactic dysphasic deficits often have accompanying production deficits that are similar in type to the comprehension problem. This emphasizes the appropriatenes of considering language as a "whole" system. Thus, patients with poor comprehension often have constriction of semantic fields (i.e., the inability to produce or recognize appropriate associates of a given word) and dysnomic or word-finding problems. Semantic error types include perseveration, jargon, paraphasia, and production of unrelated meaning strings. These errors are seen with verbal motor, or gestural expression, and are in some sense unreliable for assignment to any particular causative factor. These errors occur on tasks requiring repetition, matching, or recognition. Errors occur most typically in sentences with greater syntactic complexity (not necessarily sentence length), with words that have low Thorndike-Lorge frequency counts, and with function words. Boller et al. (1977) provide an excellent review of this area. This difficulty in comprehension of word and sentence meaning based on syntactic or semantic errors has been assigned to the parietal-temporal (+ occipital area with visual language communication errors) regions of the brain and represents a distinct step in processing from the phonemic and acoustic errors seen with temporal lesions.

A third kind of language breakdown results from injury to the anterior portion of the left hemisphere, the so-called "Broca's Aphasia". The disorder is characterized by aggramatisms (telegraphic-like speech with most function words omitted), apraxia of speech, stereotypic utterances and perseverations. These patients also exhibit difficulty in demonstrating understanding of sentences having complex syntactic construction. This particular kind of language deficit reflects the kind of system limitations imposed by limited or localized lesions. These patients, while having grossly reduced speech, typically understand at least the referential part of word meaning. While their search through memory for a word may be slowed (i.e., naming tasks), the outcome is more than infrequently successful. What may be disrupted is the patient's knowledge regarding the semantic and syntactic relations of a word to other words in the language. The more severe the expressive disorder, the more disrupted is measurable comprehension. Anterior aphasics seem to be disturbed by the form aspects of language-phonology and surface syntax, while posterior aphasics are disturbed by semantic assignments in both a paradigmatic and syntagmatic sense.

RIGHT HEMISPHERE INVOLVEMENT IN LANGUAGE

Since the right hemisphere has no functional system for expressive language in the typical human brain, it is often considered not only to be mute, but devoid of all language properties as well. Early work with the unique split-brain patient seemed to reinforce this view (Gazzaniga, 1970). Recently, Zaidel (1976) has developed a technique to provide each hemisphere with free ocular scanning of complex visual arrays (using a contact lens). His experimental findings indicate that the right hemisphere is competent to decode and associate pictures from the Illinois Test of Psycholinguistic Abilities at least at the level of a 5-year-old child. It is also able to comprehend some abstract words and is sensitive to word frequency (as is the left hemisphere), while remaining selectively poor in resolving semantic ambiguity. This ability for language processing is limited primarily to the visual modality in Zaidel's patients. That is, the visual vocabulary appears to be a proper subset of an auditory vocabulary suggesting a very poor right hemisphere capacity for grapheme to phoneme correspondence. Without access to a phonological re-coder, right-hemisphere short term linguistic memory is severely limited.

Pirozzolo and Rayner (1977) have shown the right hemisphere to be superior to the left hemisphere in recognition of visual configuration of words over brief exposure times. The right hemisphere may also be concerned with the ability to discriminate among various affective styles of speech (Tucker et al., 1977) and in evoking such varied affective tonal patterns in their own speech. Thus, the right hemisphere appears to have language processing capabilities that are primarily involved in comprehension of high frequency words by separate auditory and visual lexicons. There appears to be no syntactic rule processor nor graphemic to phonological decoder in the right hemisphere.

The disconnected right hemisphere provides evidence that suggests several alternative roles for its "language" functions. Using the Chomskian definition of language, the left hemisphere becomes the seat of transformational, grammatical, and deep lexical processes. The right hemisphere may serve as a "scout" to language understanding by allowing for parafoveal identification of visual features to help cue the left hemisphere. It may also be responsible for the "cocktail party" effect by increasing attention capacity for the kind of high frequency word (i.e., your name) recognized from across the room. In addition, during various left hemisphere malfunctions (lesions, drowsiness, concurrent tasks), the right hemisphere may help assume some of the comprehension services provided by the left hemisphere, although in a second hand or connotative fashion. In many ways, the right hemisphere language capacity is similar to that exhibited by the various primates undergoing language training (Premack, 1976).

SYNOPSIS OF LANGUAGE IN THE BRAIN

After briefly examining the evidence gleaned from various experimental studies of aphasic patients, a hypothetical system can be constructed that is not at all at odds with reported studies in psycholinguistics.

Auditory information reaches the temporal lobe where the information is coded temporally (i.e., formant transition) and into language units (phonemes and higher order unit morphemes). As information processing becomes more elaborate (lexical search), the cortical areas associated with it become more posteriorly located (parietal region). The functional asymmetries between the hemispheres in terms of cognitive processing can now be clearly seen since the left parietal lobe is able to provide for modality/featural transcriptions, sentential relations (i.e., syntactic processes) and transformational ascription. The right hemisphere is able to maintain only lower order and independent visual and auditory lexicons that appear restricted to <u>only</u> low threshold language attributes (frequency, imagery, meaning). However, it may be superior in figural identification which allows it to cue the left hemisphere for information beyond the immediate span of attention. Language information that does reach the right parietal lobe must cross the corpus callosum interacting with the language information represented in the parietal and temporal-occipital regions of the left hemisphere, the so-called angular gyrus, before being transmitted via the arcuate fasciculus and possibly other translongitudinal white matter tracts to the left frontal lobe (Broca's region) where syntactic organization is completed and speech occurs (Geschwind, 1965).

Possibly, in speech a corollary discharge occurs, sending information via translongitudinal fibers back to the parietal/temporal regions creating a language loop. In addition, vocalized language creates a second loop via the auditory system. These two loops are undoubtedly regulated in some sense by pre-frontal lobe mechanisms for speech context to time and place (Damasio, 1979). How this system may subsume Morton's logogen model and Quillian's node structures will be described shortly.

II. MEMORY

Chapter 2 describes studies of memory processes in abnormal and normal populations. The memory processes that are engaged once a word is comprehended are discussed in light of human information processing theory. Evidence gathered from neuropsychological research is supportive of certain theoretical distinctions in memory (e.g., episodic versus semantic memory; short term versus long term store). The lack of memory research with subjects whose brain lesions are relatively limited to the cortex is noted.

The model of memory proposed in Chapter 3 places both long and short term storage of complex verbal-linguistic information (words) at the cortical level. Memory processes mediated by subcortical structures are hypothesized as those governing encoding, recall, and recognition mechanisms. Research on patients with both cortical and subcortical lesions will be presented in Chapter 2. The difference in memory functioning between normal controls, patients with specific cortical lesions, and those patients with subcortical lesions is critical to any neuropsychological theory of memory. The model that is proposed in Chapter 3 will attempt to define that difference in a manner that will allow for testable hypotheses.

a. Memory studies utilizing normal subjects

As mentioned in Chapter 1 under Processing Steps, iconic and echoic stores are sensory stores that are capable of retaining briefly presented visual and auditory information (Neisser, 1967, 1976). For visual information, the decay time is approximately one second;

for auditory information, decay time is complete at approximately four seconds. This early, basic storage is apparently concerned with sensory patterns and not with the assignment of meaning. Whether an impaired echoic or iconic store could affect later memorial functioning is as yet unclear.

In day-to-day living, we are rarely exposed to such briefly (300 millesecond) presented displays of information which would severely restrict our ability to learn and process such information. To comprehend and remember linguistic information obviously requires directed attention to relatively longer displays of stimuli. It is this necessary allocation of attention that allows information to be effectively processed and maintained in short term store. Miller (1956) and others have declared that "attention" has a limited processing capacity so that we may only attend to, and store approximately 5 to 7 $\pm$ 2 bits of "chunks" of information. How we "chunk" this information is dependent both on external cues (i.e., addresses, phone numbers, initials) and intrinsic cognitive strategies (mnemonic codes).

While the allocation of attention is predominantly centered on these processes, there is also other information that may be processed but not directly attended to (in the case of word lists, the orthographic information; in the case of verbal presentations, prosody, tone of speech, rhythm, and other "non-linguistic" information). Other incidental information may also be available such as the location of objects in a testing room, scents and colors. It is important to keep in mind that our preoccupation with word lists is only to detail in a very restrictive sense, one narrowly defined aspect or process of memory.

In the case of verbal presentations of words lists, once the words are understood, what typically occurs? Waugh and Norman in 1965 described a series of experiments that showed evidence of two storage systems. They called these primary (short term) and secondary (long term) stores. Essentially, their studies varied word list length, interfering items, and inter-stimulus interval length. What they found was that unrehearsed verbal stimuli tend to be forgotten quickly because they are interfered with by later items in a series, and not because their traces decay in time. Rehearsal assisted in transfering an item from a very limited primary (short term) memory store to a longer and more stable secondary store (long term). It was shown that items may be retained in both stores at the same time. This study helped explain the importance of rehearsal processes in encoding verbal stimuli.

Glanzer and Cunnitz (1966) investigated the "inverted U" serial position curve found on free-recall tasks by varying inter-stimulus intervals and using filled and unfilled delays. They also hypothesized two distinct storage mechanisms. Glanzer and Cunitz found they could eliminate the recent or primary capacity by increasing the filled delay time between the end of the list and recall. The greater the delay, the more the curve approached positive skewing, while increased presentation rates affected the ability to rehearse and thus penalized the initial region of the curve. Atkinson and Shiffrin (1968) further elaborated upon the dual storage system. In partitioning stores, they relied heavily upon Milner's work with her patient H.M. (discussed below).

Interference tasks such as those devised by Conrad (1964) and Hintzman (1965, 1967) contribute additional information about short term store that indicates it is highly susceptible to verbal-linguistic confusions (phonemic contrasts and distinctive features), even when the stimuli are presented visually. Craik (1970) indicated that items in primary memory tend not to be as well learned as those in secondary store. Thus, short term store appears limited in capacity, dependent upon rehearsal mechanisms, and subservient to interference and decay. It seems at cursory glance to be intimately tied to the process of comprehension.

Does short term memory involve something more than comprehension? There is little general agreement on a definition of short term memory because the evidence has come from the dissimilar paradigms described above. Baddeley and Hitch (1974), using three types of tasks (verbal reasoning, language comprehension, and free recall of unrelated words) showed in all three cases a substantial impairment in performance when an additional memory load of six items (words, syllables, etc.) was imposed. A load of three items did not have a decremental effect. They described the system that was susceptible to such interference across tasks as "Working Memory". They defined it as a limited capacity work space. In this space there are trade-offs between storage load (chunks of information kept active) and processing rate. There is also a phonemic buffer (with few demands placed on long term storage capacity) or "articulatory loop" that allows rehearsal. When this rehearsal limit is exceeded, storage becomes a necessity. Thus, the span of immediate memory is set by two major factors: the capacity of this phonemic loop, relatively invariant, and the ability of the central cognitive processor to supplement this loop, both by re-coding at input and reconstruction at the recall stage. Working memory functions both during processing (listening) and retrieval (i.e., conversation recall). This executive cognitive processor will be discussed further below (under transfer to long term storage).

The "working memory" view of short term store seems more intuitive than the earlier descriptions of a short term store. For example, recency can be obtained under incidental learning conditions, even after a 30 second unfilled interval. In this situation, subjects ordinarily would have no reason to rehearse or phonemically code the items over an interval. In Baddeley and Hitch's view of working memory, time is less important than the overriding idea of similar intervening events, implicating the importance of the strategic utilization of temporal retrieval cues.

Shiffrin and Schneider (1977) consider short term store an activated subset of long term store (comprehension-semantic memory), and it is attentional processes that select the important information for maintenance, decision, or transfer to long term store. Information in short term store can be lost very rapidly, the rate of loss being dependent on the level at which information has been analyzed, on interference from similar encodings in long term store, and on background context changes between initial encoding and "test". In sum, short term store is inextricably tied up in some sense to other cognitive processes such as encoding and attention.

Before discussing encoding strategies, it is necessary to first describe the hypothesized components of long term memory. Long term store can be partitioned into episodic and semantic components (Tulving, 1972). Semantic memory is defined as a dictionary or lexicon. Since semantic memory is thought responsible for generating meaningful responses to linguistic stimuli, it may have a role in subjects free-recall word list retrieval, although it is not absolutely necessary. Hypothetically, a person could phonemically encode words or non-words for later recall without necessitating use of semantic memory. Typically, we do call upon semantic memory in free-recall tasks, if even briefly. The experimental literature is clear that pure phonemic encoding is not conducive to long term recall, although Bransford et al. (1979) have shown that this type of encoding process can lead to higher recall than semantic cuing when a rhyming strategy at encoding is paired with a rhyming cue at recall. This will be discussed further under encoding specificity.

If semantic memory represents the lexicon, then what is episodic memory's function? Episodic memory is described (Tulving, 1972) "as receiving and storing information about <u>temporally</u> dated episodes or events and the temporal-spatial relations among these events. A perceptual event can be stored in the episodic system solely in terms of its <u>perceptible</u> properties or attributes, and it is always stored in terms of its autobiographical reference to the already existing contents of the episodic memory store".

While more complex tasks requiring text comprehension and concept formation involve both systems (i.e., reading requires semantic analysis as well as the ability to form inferences from events which are read in a particular order), a simpler but just as theoretically interesting a task as word list learning and recall does not require the use of semantic analysis in conjunction with the necessary use of the episodic store. This is supported by the echolalic condition reported in adults (Geschwind et al., 1968).

Having discussed the basic structural components of memory that will be included in the model to be presented below, it is now appropriate to describe the coding or organizational operations that direct linguistic information to appropriate levels within our memory model. The term levels has typically been used within the framework of "Depth of Processing" research (Craik and Lockhart, 1972). Here, it is used to describe "transitory" states of information representation, each sensitive to particular kinds of processing demands (phonemic, semantic, reading, speaking, matching, etc.). These temporary levels may each be instantiated by the demands of the environment (i.e., experimental tasks). The instantiation may be intentional (applied cognitive strategies), relatively passive (incidental encoding strategies *dependent* on stimulus context), or some interaction of the two. These encoding operations will affect later recall or recognition (as described below).

Cognitive strategies in memory processing may be defined as the use of mediating symbols or images in order to encode and decode information in a manner that allows for increased retention and comprehension of information. There are many strategies reportedly used to enhance retention of information. To name but a few: imagery/method of loci, verbal mediation, rehearsal, rhyming, and semantic elaboration (Cermak, 1975).

The ability of a person to use such strategies effectively is governed by such variables as speaker rate of speech, rate of reading, appropriate identification of task demands, constant versus variable acoustic and visual featural information, stimulus familiarity, retention duration required, context of recall, etc. Given that we have various encoding strategies that employ different cognitive operations upon stimuli, how do these encoding processes interact with *recall and recognition*?

Tulving (1979) has presented an encoding specificity hypothesis. He claims that "the specific encoding operations performed on what is perceived, determine what is stored; and what is stored determines what retrieval cues are effective in providing access to what is stored". This holds for both recall and recognition processes (while there are some unique experimental designs that allow recall to be superior to recognition, in general, the reverse holds true). Thus, if one encodes information by rhyming, rhyming will be a superior recall cue as opposed to semantic priming. Within an encoding strategy, there appear to be several variables that may influence recall or recognition. They include distinctiveness, elaborativeness, meaningfulness, imagableness and concreteness of the stimulus. In turn, it seems that retrieval cues are effective to the extent that they induce operations or records of operations that match the original event as encoded.

Recall and recognition appear to involve similar cognitive processes that depend on internal and/or externally generated cues. Recognition depends on a semantic/lexical search plus (acoustic or visual) featural cues. Recall depends on a semantic/lexical search independent of featural cues. This finding accounts for the superiority of recognition for unusual or out-of-context items, while recall is superior for associational items, particularly if a subject adopts a "conservative" retrieval strategy. This conservative strategy is reflected by lower false-positive responses in recall and lower positive <u>and</u> false-positive responses in recognition due to the usual inclusion of semantically confusable items. Thus, recall and recognition of items are constrained by task demands, encoding strategies, and the limits of the processing system for storage.

To briefly summarize, linguistic information is first processed by feature detectors, the iconic and echoic stores. Linguistic information has order and meaning attributes which are processed in short term store via episodic and lexical operations. Linguistic information while in short term store may be subject to the various encoding processes discussed above. This is primarily dependent upon a functioning articulatory loop (as theorized by Baddeley and Hitch) which allows for verbal mediational mnemonics, covert or overt. Information is coded in episodic store for serial position and association value (i.e., syntactic and semantic operations).

From episodic memory a pointer (see logogen discussion) directs the information to the lexicon. In the case of new information, a node (Anderson, 1976) may be created at a certain threshold. In the case of old information, the threshold is lowered (and the information may be recognized). This pointing from episodic to lexical store, and the relationship among items in the lexical store, is subsumed under encoding principles. While long term storage appears to involve a strengthening of associations both within the lexicon and between time-dependent phenomena (i.e., word and text comprehension), the ability to recognize and recall items from long term store is dependent upon <u>both</u> encoding and associational properties. The ability to recall items from short term storage depends on encoding, rehearsal, and selected attentional variables.

NEUROMEMORY RESEARCH

The investigation of memory deficits in brain injured adults is one of the most promising new areas for research in neuropsychology. This is particularly true due to the recent borrowing of sophisticated methodological tools from experimental psychology. Previously, many of the reports on memory impairment in brain injured patients used the Wechsler Memory Scale (WMS), a clinical instrument based on a rather antiquated approach to the investigation of memory problems. In a recent monograph, Prigitano (1978) has scored the inadequacy of the WMS for testing visual-linguistic memory, long term memory (visual-spatial and linguistic) and criticized its unrestrained use in evaluating brain injured populations despite the questions raised regarding its construct validity for neuropathological populations (also see Russell, 1975). The introduction of experimental paradigms, such as the Peterson and Peterson task (1959), Wickens' proactive inhibition task (1970), supraspan tasks, selective reminding multi-trial free-recall tasks, and the various forced encoding tasks within the guise of various models of memory has enhanced the description of these patients.

Five types of brain-injured patients have been studied primarily. They are the Korsakoff alcoholic, head injury victims, temporal lobectomy patients, encephalitic patients, and the Alzheimer's type dementia patient. With the exception of a series of excellent studies by Butters and his associates (see below), there has been a regrettable lack of systematic exploration of memory deficits in brain lesions "restricted" to the cerebral cortex. The reason for this neglect will become apparent shortly.

Prior to the 1950's, the most frequently reported patient type was the head injury victim. Russell (1971) pioneered the study of the memory impaired, head injured patient with carefully detailed clinical and psychometric reports. He substantiated the reality of retrograde and anterograde amnesia and documented the recovery of each type of amnesia. The importance of post-traumatic amnesia as a viable prognosticator for eventual "functional recovery" from head injury was also confirmed in these studies.

In 1958, Milner (1958) reported her studies on H.M., the famous hippocampectomy patient. A bitemporal lobectomy (including both hippocampi) had been performed on H.M. in an attempt to control his seizure activity. Unfortunately, the role of the hippocampi at that time was unknown and the operation resulted in a patient with normal intellectual and language abilities, but a grossly impaired memory. This patient apparently could only learn motor tasks (by showing savings in errors over repeated trials) even though he couldn't remember previously attempting such tasks. His digit span (a measure of auditory-verbal short term memory span) was within the average range, but his long term memory for events subsequent to his surgery was practically nil. Only events prior to surgery could be recalled. The importance of the hippocampi in mediating long term memory has since been noted by Milner (1974) and other investigators (Barbizet, 1970). Because the hippocampi were variably included in surgeries to control epilepsy by temporal lobectomy, unilateral cases with complete, partial and non-hippocampi excisions were sought after (Milner, 1974). Testing revealed that the more of the hippocampus that was excised, the more serious the memory deficit. Unilateral excisions also tended to produce asymmetrical results. That is, for left temporal lobectomies, verbal/linguistic memory was most impaired. With a right-temporal lobectomy, visual-spatial memory was most impaired. Milner and others have continued this research (Milner, 1974).

Since Talland's monograph in 1965, the Korsakoff alcoholic patient has become the most studied of all the experimental groups investigated for memory deficits. Korsakoff patients are typically long term alcoholics who (when autopsy is available, show bilateral lesions in the mamillary bodies and/or the dorsomedial thalamus

(Butters and Cermak, 1980). The cause of these lesions is unknown, although vitamin B deficiency due to poor nutritional habits has been postulated as a possible precipitating factor. The most obvious cognitive deficit in these patients is an anterograde and retrograde memory deficit. They appear unable to learn or remember any new events (such as the name of the hospital they are in or their physician's name), while remembering historical/personal events in a decreasing gradient. That is, Korsakoff patients have a defect in remembering historical events that occurred during their later adult years when compared with their recall for young adult and childhood events. Whether this retrograde type amnesia gradient is greatly affected by the Korsakoff's generally low social-economic status is unknown at this time.

Korsakoff patients' immediate or short term recall of linguistic and non-linguistic information is relatively unimpaired. However, after a distracting task is imposed between stimulus presentation and recall or recognition, the patients tend to retrieve stimulus information at a chance or below chance level. That these patients have been shown to be susceptible to interference is confirmed by their great susceptibility to proactive interference (Cermak, 1979). Since interference of this type may disrupt the ability to selectively categorize, several investigators, most notably Butters and Cermak (1980), have used the levels of processing approach to help define the Korsakoff deficit as an encoding strategy deficit. That is, Butters and Cermak claim that Korsakoff patients primarily use a phonemic rehearsal strategy when storing new information. Unless a specific task that relies on phonemic encoding (i.e., rhyming) is used, this type of encoding strategy is inadequate for storing information in any meaningful manner.

In addition to a pronounced verbal memory deficit, Korsakoff patients have difficulty shifting concept hypotheses for visual-spatial or verbal stimuli. These patients are also impaired on a number of perceptual tasks that involve the analysis of complex unfamiliar visual stimuli, motor memory, and odor discrimination and memory (Butters and Cermak, 1980). Since their encoding strategies appear to be deficient, the overall memory problems found in these patients may be attributed to a generalized encoding deficit.

On the other hand, Warrington (1974, 1975) and her collaborators, using a partial cuing technique (fragmented letters), have helped improve Korsakoff patients' recall. They claim this is evidence for a decoding deficit hypothesis. In response, Cermak (1975) has shown that when Korsakoff patients use imagery to help encode paired associates, their recall is significantly improved. This finding, Cermak claims, helps point to an encoding disorder. This explanation is a weak one since normals also show improvement in paired-associate recall following imagery instructions (Pavio, 1971). More recent studies by Cermak (1979) indicate that the Korsakoff patients' "lexical" memory is relatively well-maintained, but their conceptual (or semantic) memory is impaired. For example, a progressive deterioration in reaction time and per cent correct was observed as a more descriptive decision was required of a category. Korsakoff patients continue to be employed as the typical brain injured patient in studies of long term memory deficits.

Until the early 1970's, investigation of memory functions in cortically (but without significant hippocampal or midline structural damage) injured patients was for the most part limited to severely or moderately dysphasic patients. Butters and collaborators in 1970 (see below) began what is the most illustrative examp. verbal and nonverbal memory examinations in such patients. Unfortunately, the impetus for these investigations did not spread to other investigators and but for a few studies, these cortically impaired patients have failed to generate interest as the experimental group of choice, although they are occasionally used as a neurologically impaired contrast group. There are several reasons for this relative lack of attention. The dominance of the hippocampal-mammillary body and dorsomedial thalamus structures in theories of memory has encouraged investigators to seek out human cases that fit the pathological model, and for animal experimenters to concentrate on precise lesioning in these areas. As we shall see shortly, in the simple model of memory proposed here, the cortex plays an essential although flexible role in memory storage, both in the short term and long term.

While Korsakoff and temporal lobectomy patients are clinically distinguished by <u>outstanding</u> memory deficits, the cortically damaged patient with a memory deficit often shows additional functional deficits. For example, the left cortically damaged patient will often present with outstanding dysphasic symptoms, while the right cortically damaged patient may neglect aspects of his immediate environment. These problems can be severe enough as to preclude any serious attempt to focus upon memory functions in these patients. When studies to assess verbal memory have been attempted, they have primarily been concerned with "immediate memory", perhaps biased by the rather limited language capabilities of the moderately to severely involved dysphasic patient. Thus, when reading the findings documented below, a bias in patient type selected and result explanation will become apparent which makes the generality of those findings suspect.

Luria (1976) has claimed that memory disorders can be partitioned into two distinct groups: general or modality non-specific disorders best represented by Korsakoff's patients, and partial or modality specific diseases which may reveal loss in specific comprehension spheres such as the acoustic, verbal and spatial. These partial disorders are represented by the "cortically-limited" injuries. For example, in Luria's experience, right-parietal/occipital lesions showed trace decay for visuospatial material, whereas, left temporal-parietal lesions showed decay for verbal-acoustic information. Luria also described damage to the temporal, parietal and occipital areas which caused a so-called amnestic aphasia dominated by paraphasic and semantic errors. In addition, frontal lobe lesioned patients who demonstrated high distractibility, pathological inertia and "loss of programmed forms of activity" developed a "kind of memory deficit" although Luria hesitated in describing it as a true memory deficit.

Seamon and Gazzaniga (1973) training normal subjects to utilize coding strategies on a visual probe task found that an imaging strategy led to faster latencies from the right to the left for probes, while the inverse occurred with the use of verbal strategies. They concluded that cerebral laterality effects are functionally related to coding strategies. These findings also imply an advantage for multi-coding strategies. The question of strategy effects vs. functional property in cerebral laterality will be explored later.

DeRenzi (1967) studied left and right hemispheric lesioned groups, both with and without visual field defects (implying posterior and anterior lesions), using three tasks. The first, a paired associate task using both meaningful and meaningless figures, resulted in left brain damaged patients performing significantly worse than right brain damaged patients, but with a caveat that the presence of aphasia was a critical factor in the left brain damaged patient's poorer performance. Another task utilizing meaningless but recurring figures and requiring recognition gave the right hemisphere patient with visual field defect the most difficulty. In a third task the patients were blindfolded. A tactual formboard test utilizing five trials was administered, which presumably assessed tactual and spatial learning. Interestingly on trial 1, the worst performances by both lesion groups were related to a visual field defect. But by the fifth trial, the right brain damaged patient with a visual field defect emerged with the poorest performance. A follow-up study with identically defined groups used a number of tests designed to assess verbal and nonverbal short term memory such as digit, picture and spatial span tests. The results showed both left hemisphere groups (with and without visual field defects) impaired with respect to controls and both right brain damaged groups. No differences were noted between controls and the right brain damaged groups. Non-aphasic left hemisphere patients performed as well as the right brain damaged groups on all tests except the pointing span tests where the presence of a visual field defect proved an overriding factor.

Warrington et al. (1971) found selective impairment of auditory-verbal short term memory in three patients with cortical lesions restricted to the left parietal lobe's supramarginal and angular gyri. Their predominant functional impairment was one of repetition. These patients showed a reduced recency effect on free recall tasks and also demonstrated superior recall and recognition to visual rather than auditory presentation of one to four item strings of digits or words. This modality effect also held true for the Peterson and Peterson delay conditions. Although these patients resemble conduction aphasics (Benson, 1980), Warrington et al. (1971) declare this a memory as opposed to a language disorder.

Gardner and Winner (1978) found that sound errors in repetition are most likely made by anterior aphasics while meaning errors predominate in conduction dysphasics. Delays prove useful for the anterior aphasic in improving communication. Thus both error type and delay-no delay (short vs. long term memory) conditions appear critical for differentiating memory deficits from linguistic deficits in aphasic patients. Shallice and Warrington (1977) claim that a label of "conduction aphasia" should be limited to patients with reproduction (semantic) deficits while patients with a pure repetition deficit demonstrate a short term memory disorder. This definition agrees with Saffran and Marin's (1975) findings and is derived from Warrington and Shallice's (1969) earlier reports.

Samuels et al. (1971) examined visual memory deficits in right parietal lobe patients using the Peterson and Peterson (1959) technique. On visual presentation both a control group of Korsakoff patients and the right parietal lobe lesioned patients had a steeper decay function for left visual field presentations than did normals, with the right parietal lesioned patients most impaired. Korsakoff patients showed a steeper decay for center field presentation. The right parietal patients were not affected by auditory presentations. Butters, Samuels, Goodglass and Brody (1970) had previously examined right hemisphere lesioned, left hemisphere lesioned and Korsakoff patients, essentially finding that delay conditions caused abnormally steep decay functions for left hemisphere patients on consonant and trigram recall tasks while right hemisphere patients showed abnormally steep decay functions only for visual presentations of geometric patterns. Left parietal lesioned and left frontal lesioned patients were impaired on non-delay conditions only for consonant trigrams (for both visual and auditory presentation). Left parietal patients demonstrate poor performance regardless of modality presentation in the delay conditions for both geometric patterns and consonants.

Cermak and Moreines (1976) asked five groups of patients (including left and right hemisphere patients) to detect either repeated letters, repeated words, rhyming words, or words from the same category, during the reading of a list. The aphasic patients seemed to be perfectly capable of detecting repetition when the target items were next to each other, or even when one or two items intervened. However, their performance became worse than Korsakoff patients as soon as their memory load was increased beyond this. Right hemisphere patients were least impaired of the organic groups and it is not clear whether a general organic factor is involved in their mild memory deficits or a specific right hemisphere linguistic dysfunction. The aphasic's performance on the category and semantic conditions approached normal when presentation rate was slowed, but remained impaired for phonemic repetitions (rhyming). It appears that speed of processing affects the aphasic's retention capability as well as his potential to analyze the semantic properties of words.

Albert (1976) gave tests of short term memory for objects and sequences of objects to patients suffering unilateral cerebral damage with aphasia, unilateral cerebral damage without aphasia, and a control group. Results showed that aphasics have significantly impaired auditory short term memory, both for total verbal item information and for verbal sequences. This is not due to information load, as the aphasics still had significantly more omissions than the other groups for short sequences (2 items). For high information load, defective memory for sequences becomes a critical factor. The fact that each patient had at least 18 objects that could affect his decision process was not investigated. The effect of decision versus memory processes as measured by signal detection analysis may be a useful tool when recognition is involved as a task variable with dysphasic patients.

Locke and Deck (1978) had five aphasic adults nonverbally recall individualized lists of pictures they could easily name and lists of pictures they could not name. Final items in the two lists were recalled with equal accuracy. It can be argued that this recency effect is due to short term phonemic encoding. The aphasic had greater loss of primary position recall on the names rather than the un-named list when compared to medial positions. This effect could be due to a rehearsal strategy that involved repetition of medial items at the cost of more initial ones. DeRenzi et al. (1978) examined control, aphasic, and two non-aphasic brain injured groups on three delay conditions (following the commands) on the Token Test. There was a no delay condition, a 20 second unfilled delay, and a 20 second filled delay (counting task). In the no delay and unfilled delay conditions, there was no significant difference between any of the groups. The distraction task brought about a significant decrement in every group. However, the aphasic group's decrement was significantly worse than either of the other two groups (no significant difference between controls and non-aphasic groups). This significant difference remained even when initial comprehension effects were covaried. In another experiment in this study a 4 second pause was inserted between the end of the command sequence and the beginning of counting activity. This 4 second pause did not benefit the aphasic's performance.

Ojemann (1978) measured short term verbal memory performance during electrical stimulation of human left frontal-parietal-temporal cortex during a craniotomy under local anesthesia for the treatment of medically intractable epilepsy. Memory was tested by a task that required object naming, followed by interference , which was followed by recall and recognition (only following a subsequent trial). Stimulation current levels were subthreshold for language disruption and were applied randomly to the naming, interference and recall conditions, but not the recognition condition. Results indicated that those areas of the cortex concerned with language (disrupted by stimulation during naming) and those concerned with short term verbal memory are separate but adjacent. At sites adjacent to the posterior (posterior temporal-parietal junction) language area, stimulation during input, and particularly during storage, disturbed short term verbal memory, while stimulation during output generally did not. Output stimulation affected memory only when stimulation occurred in the frontal lobe near Broca's area. These errors were omissions and could be rectified following stimulation.

These brain stimulation findings are complemented by recent electrophysiological research using scalp recordings of event-related potentials (i.e., evoked potentials). While memory processes themselves have not been investigated within the confines of a fruitful paradigm, some preliminary work on language processing in the cerebral cortex has taken place. By extrapolating some of these findings we can place them in the context of time and spatial location to help support behavioral evidence gathered from brain injured patients. Galin and Ellis (1977) used Fourier analysis of amplitude characteristics of the EEG over time and found alpha suppression in the left hemisphere for linguistic tasks and alpha suppression in the right hemisphere for visual-spatial tasks. These findings were consistent across subjects. Chapman et al. (1977) found reliable evoked potential differences between semantic meaning classes as predicted by Osgood's quantitative analysis of semantic meaning (however, Chapman's conclusions are based on relatively little data). These preliminary data provide support that evoked potential variability to different verbal stimuli may be related to levels of linguistic processing. Marsh and Brown (1977) have shown that different evoked potential waveforms to the same word are dependent upon the context (adjective vs. noun) in which the word is placed. They argued that the evoked potential shape (i.e., amplitude over time) interacts with the lexical <u>and</u> syntactic demands of the stimulus environment.

Wood (1977) has found evoked potential differences with the same acoustic sounds dependent upon whether they occurred in isolation or in phonetic context. Interestingly, although Roemer and Teyler (1977) found evoked potential changes dependent upon grammatical usage of words (i.e., changing the meaning), they found similar waveform shapes in <u>both</u> hemispheres. However, as in most of the above studies, the left hemisphere had a greater amplitude in the P300 peak (a positive waveform that occurs in the evoked potential approximately 300 milleseconds post-stimulus onset), which is generally considered an indicator of cognitive activity (decision making).

To summarize, evoked potential waveform data have been able to discriminate between different linguistic classes (phonemic, grammatical and semantic) over a large number of studies. Interhemispheric waveform comparisons typically show higher amplitude activity for language processing over the left hemisphere (temporal-parietal region), although waveform shape may be coherent between hemispheres. At this time, the evoked potential data are based on limited electrode placements or on complex intra- and interhemispheric coupling, while data regarding coherence analysis and relative appearance of waveforms over time are lacking.

III. INTEGRATION

Below is presented a hypothetical information processing system suggested by the studies presented above. These studies have been cited to emphasize the enormous complexity of memory processing in the brain and to underline the theory-dictated methodology of most contemporary laboratory investigations of memory processes. Nevertheless, it is important at this point to propose a simple general theory for the attributes of a human verbal-memory system.

Linguistic communication is first coded via the various peripheral nervous system end organs (i.e., eye, ear, etc.). Presumably, the sensory information store is generated from these end organs (and perceived in the cortex), but verbal information in this store rapidly decays unless there is continued exposure of the verbal information for further cognitive processing (Massarro, 1975). Linguistic systems are distributed throughout the cerebral cortex receiving input from tactual, visual, and auditory sensory pathways. Basic sensory areas such as for hearing and vision accept verbal information in a non-semantic (although under the influence of attentive processes) but discriminative fashion. That is, linguistic stimuli are processed into relatively discrete components, i.e., categorical/ phonemic segments (but see description of speech spectrography in Massarro, 1975) that simplify the information value of the linguistic units for adjacent cortical regions.

Whether discussing the visual features of letters, the acoustic parameters of a noun, etc., the basic cognitive operation begins in what the author has chosen to identify as a non-semantic but discriminative and perceptual fashion. Since the author deliberately reviewed verbal memory processes, the hypothetical path he now will lead you down is that utilized for the processing of a (word list) free-recall task by a normal human subject. Verbal stimuli would initially be processed in each hemisphere in the superior temporal cortex. Bilaterally, the verbal-linguistic processing systems interact via short intrahemispheric tracts with adjacent cortical regions. For the right hemisphere, this means a minimally participating "semantic" memory, primarily composed of concrete and high-imagery nouns organized in a rather random fashion. It is hypothesized that this lexical store is directly associated with the ability of the subject to meaningfully manipulate an environmental object or perform a meaningful act (thus emphasizing the imaginal attributes of a word) and is located in the right temporal-parietal region. Whether right hemisphere memory ability contributes to a verbal memory task performance is doubtful, as Zaidel (1978) has shown it has a rapidly diminishing recall function in the split-brain patient. In addition, Zaidel reports that the ability of the right hemisphere to encode auditory information using a verbal mnemonic or linguistic strategy is extremely limited.

In the left hemisphere, verbal information is processed in the angular gyrus and temporal-parietal region, leading to storage in the manner proposed by the hypothetical semantic and/or lexical memory models of Collins, Rosch, Loftus, etc. This lexical structure has any one of a number of possible organizations, based on variables such as imagery, concreteness, hierarchical categories (i.e., animal-bird-wing), etc. Comprehension, or the assignment of meaning to verbal utterances, predominantly takes place in this region (left-temporal/parietal) of the brain (there is an open question as to how linguistic information becomes decoded before reaching this semantic store). After verbal-linguistic information is semantically identified, the subject has the option of various encoding strategies. These encoding strategies are based on description variables from the same lexical store referred to above (and now including the right hemisphere lexicons). Thus, in normals, the right hemisphere lexicon is used primarily for strategic encoding, but not passive syntactic/lexical identification.

At this point both hemispheres are active in comprehension of language. The left hemisphere may engage the right hemisphere by signaling, probably in conjunction with critical bifrontal lobe activation, via the corpus callosum for the right hemisphere to create an image of the stimulus. Strategies of this type were discussed earlier in this paper under encoding and are used variably by the subject. Unless controlled for by experimental manipulation or instruction, the strategy(s) used cannot be predicted. A typical strategy (in verbal memory) involves conscious rehearsal of verbal items. As verbal mediation or interpretation is carried out, short term memory is instantiated. Short term memory <u>is</u> defined by the decay rate following the comprehension of verbal information (see Peterson and Peterson, 1959). As verbal linguistic processing engages left pre-frontal and frontal cortex (Broca's area) for expressive purposes, presumably via the arcuate fasciculus (Geschwind, 1965) from the parietal lobes, it utilizes working memory, taking advantage of articulatory rehearsal to keep information in short term store. This articulatory rehearsal is accomplished with the participation of Broca's area cortex.

Simultaneous with verbal mediation processes, linguistic information is transferred to the hippocampi from the temporal-parietal area of each hemisphere and the left frontal lobe area. While the question of hippocampus storage and coding of information is still speculative, the author suggests that the hippocampus is specialized for interpreting semantic context and what kind of information it receives from the cortical and subcortical regions of the brain. Hippocampal processing interacts with the hypothalamus/pituitary stalk so that neuropeptides and other neurohormones are utilized in the cortical areas where the cognitive information in question is being retained in short term store. Those cortical areas are essentially tagged by the hormonal or peptide messenger. This creates a biochemical and electrophysiological transfer mechanism from short term store to long term store.

Dependent upon the demands of the task, and the encoding strategy used by the subject, the depth of encoding phenomena operates in conjunction with transfer of verbal information to long term store. Rehearsal via an articulatory or imaginal loop facilitates the storage process. In fact, other environmental information that actually occurs in conjuction with, or that the subject perceives to occur in conjunction with the verbal stimuli, may also be encoded, but lowered threshold for recall occurs only in those parts of the brain where a subject-generated strategy (for example, imagery and the right hemisphere) is dominant (i.e., has a propensity for being processed). Regardless of whether a subject supplies his own cues (in recall) or relies upon the addition of environmental cues (in recognition), his retrieval process also engages frontal lobe categorizing mechanisms for semantic organization which in turn supports the various search tactics posited by the experimental investigations cited in the review (i.e., Collins and Quillian based models). While the present model being proposed here is only speculative and preliminary, it does provide several testable hypotheses, plus justifying the type of experimental tool that is proposed to be used in this study.

IV. TECHNIQUES TO BE USED FOR EVALUATING VERBAL MEMORY PROCESSES

a. Selective Reminding Test

The most widely used clinical test for memory is the Wechsler Memory Scale. It has been used in numerous studies with brain-injured populations. Yet the inadequacy of its diagnostic and prescriptive claims has been discussed in a recent Journal of Clinical Psychology monograph (Prigitano, 1978). While Wechsler is in the process of revising the test to make it more sensitive to hemispheric asymmetrical processes and strategy systems (Wechsler, 1978: personal communication), its simple paired-associate and paragraph recall subtests do not offer the kind of flexibility in administration and scoring that is necessary to parcel out stages of memory or important memory process variables (i.e., imagery, spacing, etc.). The other major clinical standardized memory tests such as the Benton Visual Retention Test, Kohs Blocks, and Kimura Recurring Figures are purported to measure nonverbal visual-spatial memory only. Thus, the construction and validation of a new clinical device for evaluating verbal/linguistic memory would prove beneficial both to the clinician and the experimentalist.

The basis for such an instrument can be found in the Selective and Restricted Reminding Tests originally devised by Buschke (1975). These tests as conceived by Buschke are multi-trial free-recall tasks. The Selective Reminding Test requires the experimenter to remind the subject of only those words the subject forgot on the previous trial. With Restricted Reminding, the subject is only reminded once for each word. On the remainder of the trials, recall is non-cued for that particular word regardless of its absence on a particular trial. These tests allow for the analysis of variables such as retrieval, encoding, consistent retrieval, long term and short term retrieval, total recall, and cluster analysis of recall. In addition, word list length and word variables such as word frequency, letter bigram frequency, imagery rating, category rating, concreteness rating, word length, and orthographic and phonemic representation can be manipulated. Because the test may more closely mimic the way we try to learn verbal word lists (selectively), it may have greater ecological validity than many tests. Its historical use is briefly described below.

Buschke (1974) examined the ability of "normal subjects" to recall list items after recall failure in a restricted-reminding paradigm. He divided his subjects into three experimental groups: 1) immediate verbal recall, 2) immediate written recall, and, 3) verbal recall, following interference. The stimuli included a twenty item list of animal names and a twenty item list of unrelated nouns. Results showed that nearly all twenty items for each group entered long term store as shown by spontaneous (i.e., unreminded) retrieval on at least one trial. Once an item was spontaneously retrieved, it was usually consistently retrieved. Mean recall per trial was fourteen words, leading one to suspect that most recall failure was due to retrieval failure rather than loss of information since most words were spontaneously retrieved at least once. An interesting observation was that those items that are spontaneously remembered are usually retrieved late in the recall process of each trial. Even group 3 (with the verbal interference condition) performed on a par with the other groups suggesting that retrieval on this measure is from long term store rather than short term store. When Fuld (1976) adapted this technique for Korsakoff patients, she found that items fluctuated in their retrievability. Patients recalled from long term store only about half the number of items recalled by controls. In addition, these patients showed no improvement in total recall over trials.

Fuld and Buschke (1976) using probability statistics have demonstrated the existence of two stages in competency in retrieval from long term storage. Using normal subjects in standard restricted/selected reminding tasks with single and mixed category lists, they demonstrated that the probability of item recall does not increase prior to the abrupt onset of consistent recall. Extended effort (giving the subject more time) in recall significantly improved total retrieval, and the fact that this occurs shows that recall time restrictions in standard multi-trial free-recall paradigms do not encourage exhaustive retrieval. This is important for those psychologists who use such tests for prognostic reasons (e.g., head trauma patients' employability). For those items not immediately retrieved, further extended trials demonstrated the eventual retrievability of almost all items earlier deemed lost. There was no significant difference in total recall between related and unrelated category lists. To reiterate, no patient group showed any increase in the proportion of items recalled before the onset of consistent retrieval. Recall typically increased during such verbal learning not because the probability of recall of each item increases, but rather because more items are transferred from a stage of inconsistent retrieval to consistent retrieval. This is where the failure of Korsakoff patients appears. They are unable to utilize the neuropsychological systems that support consistent long term retrieval, and at best have only reduced inconsistent retrieval with no increase in mean item recall over trials.

Buschke (1977) has also investigated the organization of retrieval in this kind of paradigm. He noted that items are spontaneously clustered into many small recurrent chunks that remain intact when the basic chunks become grouped in higher-order chunks. To study this phenomenon in greater detail, Buschke presented 40 unrelated items to normal subjects. Results showed that as learning progressed, subjects retrieved more chunks without interposition of individually retrieved items, and developed an extensive and persistent higher-order organization of the basic chunks formed during learning. In a more elaborate study, Buschke (1979, personal communication) replicated the basic results reported above, and confirmed the finding (using a written response for recall) that most recurrent sequences or chunks do represent clustering by specifying the actual word clusters in each recall. Often larger word clusters are made up of several sub-clusters. Recall of single items remains inconsistent, whereas consistent recall of items usually involves a cluster process and is responsible for an increase in total recall over trials. This ability to cluster may be tied to the encoding strategies used by normal subjects. A failure of semantic encoding strategies could lead to poor clustering by Korsakoff patients. The transfer of information from inconsistent to consistent retrieval along with the appearance of clustering may indicate the point at which information is transferred from temporary storage to permanent storage (i.e., consolidated) and should be useful in clinical assessment of brain injured patients.

This brief review of the selective/restricted reminding procedures suggests that a paradigm of this nature might be useful as a clinical research tool for the investigation of memory processes. The use of brain-injured patients as subjects allows the investigator to selectively identify various factors involved in memory processing (see section on neuropsychological approaches to memory). As will be described in the methodology section, the Buschke paradigm was adapted to evaluate particular groups of brain-injured patients in order to examine the validity of the model of memory proposed in Chapter 3.

b. Recognition Memory Test

Another method for evaluating memory is to present verbal information at one point in time and then, following some variable delay period, to present the same verbal information (considered the targets) mixed among distractor verbal information (foils). An example of this kind of task would have a subject being asked to listen to and remember twenty words from a specific category (e.g., vegetables). The subject is then given a distractor task (e.g., arithmetic calculation problems) to perform for two hours. Following this task, the subject is presented with a large list of words individually printed on index cards. Some of the words are targets and some of the words are foils. The subject's task is to decide which word is a target (and say yes) and which word is a foil (and say no).

The subject's decision as to which stimulus item is a target or foil may depend on a number of variables. It is conceivable that target items (i.e., words) have lower thresholds for recognition (Morton, 1970) which influences the subject to make a positive response. On the other hand, a subject may also assume a subjective criterion level for deciding whether a stimulus is a target or a foil. This criterion level is theoretically independent of the stimulus threshold (i.e., stimulus detection process). One attempt to operationalize this distinction has been to adopt the Theory of Signal Detection for analysis of recognition memory scores (Egan, 1958; McNicol, 1972). There are also several Correction-for-Guessing formulas (e.g., hits minus false-positive responses) that have been used to compensate for guessing strategies based on individual idiosyncratic criterion levels (McNicol, 1972).

Another variable that affects the decision process is the nature of the foils themselves. They can be related in a variety of ways to the target (e.g., acoustically, orthorgraphically, or semantically) or not at all (e.g., random items). The more related the foil to the target, the more difficult the recognition decision should become (Underwood and Freund, 1968). There are, of course, many more variables that may affect the recognition process (e.g., encoding operations on the stimuli during their initial presentation).

Recognition processes are often compared to recall processes in an attempt to ascertain both the uniqueness and similarity of each. A very general finding is that recognition of previously presented verbal information is superior to recall of the same verbal information (Mandler et al., 1969). This finding indicates that subjects may learn considerably more than is apparent from their recall attempts.

That subjects may learn considerably more than is apparent from their recall attempts is a particularly important point if an experiment or a clinical evaluation is concerned with the verbal learning process of a brain injured adult. For instance, in the case of the selective reminding free-recall test previously described, there is a scoring procedure that purports to indicate whether an item has been encoded into long term storage or not. This is determined by observing if an item has been recalled by a subject for two consecutive trials without reminding. Those items that need continuous reminding (with or without being recalled) are assumed not to have been encoded into long term storage. Since it has been documented (Mandler et al., 1969) that recognition is usually superior to recall, the selective reminding procedure that indicated whether an item has reached long term storage should be appended to read "long term storage under free-recall conditions," a caution not typically mentioned in the literature (Fuld, 1976).

The advantage of including a recognition test in the evaluation of brain-injured subjects is its' ease of administration, only a simple response is usually required (i.e., a yes or a no), and the foils can be experimentally manipulated to test hypotheses regarding the type of deficit suspected in a particular brain-injured population. The use of such a test in conjunction with a selective reminding free-recall task would be most judicious when evaluating the verbal learning process in brain-injured patients.

c. Word Fluency Test

In contrast to such tasks as free-recall or word recognition which theoretically are dependent upon episodic processes, there is a simple task which can be utilized to reveal adequacy of searching and retrieval from semantic memory (i.e., the lexicon) independent of episodic processes. This task requires a subject to produce as many words as he can within a specified period of time under category constraints. This word fluency task has been used extensively in the evaluation of expressive verbal performance in brain-injured adults and is considered sensitive (in some forms) to lesions in almost all regions of the brain (Goodglass, 1980).

The word fluency task is typically partitioned into category and letter fluency. Category fluency (e.g., "Name as many vegetables as you can in 60 seconds") can be described as the subject reporting a search through semantic memory constrained by a specified category, usually beginning with typical exemplers and ending with fuzzy (or so-called low typicallity) category members. In a letter fluency task (e.g., the subject is told to name as many words as he can that begin with the letter 'V' within 60 seconds), the subject's search is generally acoustically/phonemically based. Howes (1978) has hypothesized that these retrieval processes (i.e., phonemic and semantic) are independent searches of a single lexicon. Failures of category naming are found very rarely, usually only in the more advanced or acute stages of central nervous system dysfunction, whereas disorders of letter naming are quite common.

Due to the relative simplicity in administration (and response requirements) of this task, it can be utilized with even the most severe types of brain-injured subjects and provides for a measure of ease of semantic retrieval and search that can be contrasted with episodic retrieval processes.

d. Summary

The tests described above have long been used in both clinical and experimental examinations of memory functioning (Baddeley, 1975). They are relatively easy to construct, simple enough for most brain-injured subjects to understand, and are flexible enough to be administered at bedside or in a laboratory. In addition, since numerous studies have already been performed with the tests described above, interpretation of result patterns is less subject to controversy.

Chapters one through three presented an overview of memory research with normal and abnormal populations and a simple model that tries to take into account findings from research with both kinds of populations. A concern was raised that studies of abnormal populations have tended to exclude patients with cortically limited lesions. A reason often given is that dysphasic or perceptual disorders may confound the results. It also appears that there is a belief that these patients would not be theoretically interesting to study. This author rejects that notion and proposes that cortically lesioned patients without confounding dysphasic and perceptual disorders can be found and systematically investigated.

The model proposed in Chapter 3 suggests that memory storage is distributed throughout the cortex and that different cortical areas subserve different aspects of memory processing. It follows that cortically lesioned patients, whose lesions do not extend into the classical limbic-memory areas (e.g., the hippocampus, medio-dorsal thalamus, etc.) would nevertheless be impaired for specific aspects of memory functioning. If that is the case, we stand to learn as much about how memory is processed and stored from these patients as from the classical limbic-system damaged amnesic. In response to this gap in neuropsychological research, the present study has been designed and implemented to determine whether in fact cortically lesioned patients do have verbal memory deficits independent of more basic dysphasic and perceptual deficits, and if present, whether these verbal memory deficits can be explained within the context of the theory proposed in Chapter 3. The hypotheses tested and the methodologies used are described below.

V. EXPERIMENTAL METHODS

The present experiment is designed to examine verbal memory processing in patients with cortical lesions. The first hypothesis (#1) to be tested is that left-cortically damaged patients will be significantly inferior on total recall, retrieval, and storage measures for early trials on the Selective Reminding paradigm (see below for test description) when compared to right-cortically damaged patients and controls. This finding is expected because the left hemisphere's role as a phonemic processor for language sounds is unique (see review and model chapters). Both the left and right hemispheres demonstrate some capacity for semantic storage. In addition, the patients being tested should have relatively intact hippocampal/limbic structures suggesting that the long term retrieval processes should be adequate for the task demands in this experiment. Therefore, given some impairment in phonemic processing in left cortically lesioned (non-aphasic) patients, it is hypothesized that these patients will have marked difficulty in initially discriminating among, and encoding, verbal stimuli. Since this phonemic processing deficit is an inconsistant phenomenon that does not occur for every single word or word-type, it is expected that frequent reminding or repetition of a word will overcome the initial encoding problems allowing for increased retrieval over trials. The predicted encoding deficit will be apparent on total recall, retrieval, and storage measures on the Selective Reminding Tests.

lesions. A reason often given is that dysphasic or perceptual disorders may confound the results. It also appears that there is a belief that these patients would not be theoretically interesting to study. This author rejects that notion and proposes that cortically lesioned patients without confounding dysphasic and perceptual disorders can be found and systematically investigated.

The model proposed in Chapter 3 suggests that memory storage is distributed throughout the cortex and that different cortical areas subserve different aspects of memory processing. It follows that cortically lesioned patients, whose lesions do not extend into the classical limbic-memory areas (e.g., the hippocampus, medio-dorsal thalamus, etc.) would nevertheless be impaired for specific aspects of memory functioning. If that is the case, we stand to learn as much about how memory is processed and stored from these patients as from the classical limbic-system damaged amnesic. In response to this gap in neuropsychological research, the present study has been designed and implemented to determine whether in fact cortically lesioned patients do have verbal memory deficits independent of more basic dysphasic and perceptual deficits, and if present, whether these verbal memory deficits can be explained within the context of the theory proposed in Chapter 3. The hypotheses tested and the methodologies used are described below.

V. EXPERIMENTAL METHODS

The present experiment is designed to examine verbal memory processing in patients with cortical lesions. The first hypothesis (#1) to be tested is that left-cortically damaged patients will be significantly inferior on total recall, retrieval, and storage measures for early trials on the Selective Reminding paradigm (see below for test description) when compared to right-cortically damaged patients and controls. This finding is expected because the left hemisphere's role as a phonemic processor for language sounds is unique (see review and model chapters). Both the left and right hemispheres demonstrate some capacity for semantic storage. In addition, the patients being tested should have relatively intact hippocampal/limbic structures suggesting that the long term retrieval processes should be adequate for the task demands in this experiment. Therefore, given some impairment in phonemic processing in left cortically lesioned (non-aphasic) patients, it is hypothesized that these patients will have marked difficulty in initially discriminating among, and encoding, verbal stimuli. Since this phonemic processing deficit is an inconsistant phenomenon that does not occur for every single word or word-type, it is expected that frequent reminding or repetition of a word will overcome the initial encoding problems allowing for increased retrieval over trials. The predicted encoding deficit will be apparent on total recall, retrieval, and storage measures on the Selective Reminding Tests.

task that requires a discriminative retrieval and matching process (in the presence of both target words and semantic/phonemic/random foils) should be especially difficult for those patients with left hemisphere lesions. A stimulus discriminability measure should be most sensitive to this particular difficulty.

Hypothesis #5 states that for left hemisphere damaged patients, the predominant error type will be a phonemic confusion, and for the right hemisphere damaged patients the predominant error type will be a semantic confusion. This will be assessed by a comparison of the ratio (score) of phonemic to semantic errors on the Word Recognition Test. The left hemisphere lesioned patients should have an impaired phonemic recoding mechanism. Therefore, they will tend to leave out some critical phonemic features that help distinguish target stimuli from possible distractors. Patients with right hemisphere lesions should not demonstrate impaired phonemic processing as there is no evidence of such a specialized processor in the right hemisphere. When patients are confronted with targets and distractors on the Word Recognition Test, it follows that any false-positive responses occurring (because of impaired right hemisphere lexical structures) should be of a semantic nature.

Hypothesis #6 states that in order to prove that the left hemisphere lesioned patients' deficits on verbal processing tasks are not simply part of a generalized deficit, a d', hit, and error analyses will be computed for each group on the Kimura Recurring Figures Task with the hypothesis that ANOVA computations will

One Selective Reminding Test is composed of only high frequency/imagery words, another only low frequency/imagery words. Hypothesis #2 states that there will be an interaction between frequency and subject type. That is, the brain injured groups are expected to demonstrate poorer recall than controls, particularly for low frequency/imagery words. Since both cerebral hemispheres demonstrate a capacity for semantic storage, it is expected that unilateral cortical lesions will reduce the storage capacity of those semantic structures. This reduction will take the form of higher thresholds for word accessibility. This threshold elevation should take its severest toll upon low frequency/imagery words, or those words with already high thresholds before structural damage.

Hypothesis #3 states that word fluency performance should be correlated with free recall performance when lexical search and retrieval processes are impaired due to the lexicon itself being damaged. Therefore, fluency output, given letter and category stimuli, will be compared to first trial total recall averages on the Selective Reminding Tests for the experimental and control groups.

Hypothesis #4 suggests that the left cortically damaged group will have a $\bar{x}$ d' (defined as a measure of stimulus discriminability) score that is significantly inferior to the $\bar{x}$ d' scores for the control and right cortically damaged groups on a delayed word recognition test for those items contained in the original selective reminding task. Since left hemisphere lesions should impair both phonemic <u>and</u> semantic processing mechanisms, a word recognition reveal the right hemisphere lesioned group to be significantly inferior to the control and left hemisphere lesioned groups. The Kimura Recurring Figures Task requires visual-spatial perception and memory processing relative to linguistic processing. Thus, right hemisphere lesioned patients would be expected to perform more poorly on this task due to the right hemisphere's purported dominance for this mode of processing (visual-spatial).

If these six hypotheses are supported, they will form the basis for the part of the theory proposed earlier that located short term or "working" memory as well as lexical structures in the cortex, to the exclusion of long term storage and recall processes which are generated by subcortical mechanisms. As long as any lexical space survives a cortical injury, it should be accessible via long term retrieval processes. In addition, if the selective reminding paradigm provides useful information, its legitimacy as a clinical instrument will be strengthened.

SUBJECTS

Subjects include 18 controls without a history of neurological disorder, 18 patients with verifiable right-brain damage exclusive of hippocampal-limbic regions, and 18 patients with verifiable left-brain damage exclusive of hippocampal-limbic regions. They constitute the primary experimental contrast groups. In addition, a Korsakoff patient subgroup (presumably with subcortical pathology), too small in number (6) for inclusion for statistical analysis, will be qualitatively compared with the formal experimental and control groups.

Control group members were recruited from non-brain damaged patients and medically healthy staff employed at the Clinical Science Center, University of Wisconsin-Madison. Right brain damaged and left brain damaged subjects were selected from the inpatient and outpatient services at Madison General Hospital, the William H. Middleton Veterans Administration Hospital, and the University of Wisconsin hospitals and clinics. All patients were right-handed, between 18 and 65 years old, had completed high school, were of normal intelligence (estimated premorbid Full Scale IQ of 85 or higher, as judged by previous psychometric testing, education, or vocation), were medically stable, did not present with a clinical aphasia, and were seen at least one month following receipt of the neurological diagnosis assigned each subject.

The overall $\bar{x}$ age was 56.5 and the overall $\bar{x}$ education level was 12.52. There was no significant difference between groups for either measure as determined by a one-way analysis of variance. Right and left brain injured patients included in this study had documented radiological evidence of the size and location of their lesion (verification was made by the computer axial tomography scan, arteriogram, brain scan, etc.). Patients recruited had lesions neurologically judged to be limited to the cortical areas supplied by the middle cerebral artery (all were stroke patients). This selection criterion enables testing of patients whose lesions lie in the areas purported to contain the lexicon (see the theoretical model presented in Chapter 3). Patients across groups (left and right cortically injured) were matched as closely as possible for size and location of lesion. The above-mentioned radiological procedures helped exclude patients with lesions of the medial temporal lobe (including hippocampii), ocipital lobe, pre-frontal lobe, midline limbic structures (mediodorsal thalamus or mammillary bodies), and the midbrain/brain stem regions. It should be noted that "cortically damaged" usually means inclusion of subcortical layer white-matter tracts and limited subcortical nuclei since lesions truly restricted to the cortical layers are extremely rare in humans. Random sampling procedures, given the availability of such patients, are too time consuming and inappropriate for the abnormal population to be studied (random sampling with brain-injured patients takes on the guise of statistical appropriateness, but admissions to hospitals are biased by holidays, time of year, socioeconomic status, etc.; therefore, most investigators prefer a policy of selection based on consecutive admissions over a pre-defined period of time or availability of patients within a selected period of time). A total "N" of 54 subjects is available for the statistical analysis, plus the addition of 6 Korsakoff patients (obtained from the Northhampton Massachusetts Veterans Administration Hospital) for qualitative comparisons. Subjects in the present experiment had not participated in any selective reminding memory experiment prior to the present procedure. All subjects were tested and all data analyzed by the author.

INSTRUMENTATION AND MEASUREMENT

The Selective Reminding Test was devised for use with clinical and normal populations. Presentation to the subject is by experimenter voice. The subject also responds verbally. An example of the Selective Reminding Test scoring protocol is shown in Appendix I.

The Kimura Recurring Figures Test required the subject to recognize geometric and nonsense designs. This test was scored for number correct and false-positive responses for geometric, nonsense, and total categories.

The Word Fluency task required the subject to name as many words as he could within one minute's time within a category boundary (letters, animals, etc.). Certain restrictions are placed upon the subject. No proper nouns are accepted, no numbers, and no suffix-added words (e.g., beat-beater). Borkowski et al. (1967) have shown this test to be sensitive to cerebral dysfunction.

The final task was a Word Recognition Test. It consisted of the 22 original word stimuli used on the selective reminding tests. In addition, there were three kinds of foils (unrelated, phonemic and semantic) for each stimulus word. Words were presented on index cards (bold black print on a white background, 4½ x 6 inches) with one word per card and each card presented one at a time. The subject was asked to respond yes or no, that the word did or did not appear on either of the selective reminding word lists. The rules for the selection of the foils were as follows. For *phonemic* foils, the sound blend of the initial consonant-vowel cluster and the final vowel-consonant cluster were chosen to match as closely as possible the target item. For the semantic foils, a word was chosen to be in the same general category (a super-, sub-, or co-ordinate) as the stimulus item. The unrelated foil was chosen to have no relationship (semantic or acoustic) to any target word.

PROCEDURES

The testing always took place in a well lighted room that contained a table and two chairs. This was typically a Neuropsychology testing office. Some cases necessitated testing be done at bedside. In those cases, the patient's room was adjusted to simulate, as closely as could be arranged, the testing office. The examiner briefly explained to each subject the nature of the experiment. "This is an experiment to help us learn about memory and the brain. You can help us by doing your best on the problems I will give you." The first task administered was the Selective Reminding Tests. The examiner instructed the patient in the following manner. "I'm going to read to you a list of words. Please listen carefully, for when I am finished reading to you, I will expect you to remember all the words on this list. You will have many chances to remember the whole list. I will not be able to answer any questions once we begin. Are you ready? Listen carefully." The list is then read at the rate of 1 word every 2 seconds. Following the list presentation, the examiner said: "Now I want you to tell me all of the words on the list that I just read.

Tell them to me in any order." If more than 10 seconds elapse without a response, the examiner asked "Can you think of just one more word?" If the patient replied no, if 10 more seconds elapsed, or the subject repeated 3 previously recalled items in a row, then that particular trial was terminated. Before beginning the next trial, the examiner said: "I am now going to read to you only those words on the list that you forgot this last time. After I read these reminders to you, I'm going to ask you to recall these words, and all the other words on the list, one more time." Following this reading, the examiner said: "Now I want you to tell me all the words on the list." This procedure continued through all 10 trials.

The Recurring Figures Test followed immediately and was introduced to the subject by the examiner as follows: "I'm going to show you some designs, one at a time, and I want you to look at each one very carefully and try to remember it." The 20 stimulus cards were then shown at a one card every 3 second rate. Following the showing of the 20 stimulus cards, the examiner gave the following instructions: "Now I'm going to show you some of those designs again, along with some new ones that you haven't seen before. Each time I show you a card now, I want you to say yes if I've shown the picture to you before, or no if you haven't seen it before. Are you ready? Let's begin." If a subject did not respond with a yes or no quickly (5-7 seconds), he was prodded (say yes or no).

The Word Fluency Test immediately followed with these instructions: "I will say a letter of the alphabet, then I want you to give me as many words that begin with that letter as you can, as quickly as you can. For example, if I say, "B", you might give me "bag, bottle, bed." Do not use words that begin a capital letter like names of places or people such as "Boston" or "Bob." Also, do not give numbers, or the same word but with a different ending, for example: "beat followed by beating." Do you have any questions? Begin when I say the letter. The first letter is _____." Following the letter fluency task, the subject received these instructions: "I will now say a category name, then I want you to give me as many words as you can that fall into that category, as quickly as you can. For example, if I say "trees" you might give "oak," "pine," "maple." Do you have any questions? Begin when I say the category. The first category is _____." Sixty seconds were allowed for each letter or category. There were 4 letters (f,s,p,t) and 4 categories (furniture, animals, cars, and countries) tested.

The Word Recognition Test immediately followed the Word Fluency Test. The instructions for this task were: "Now I'm going to show you a lot of words, one at a time. Some of these words were on the lists I read to you and asked you to remember in the beginning of our session. I want you to tell me "yes" if it was and "no" if it wasn't. Are you ready? Do you have any questions? Let's begin." If subject did not respond quickly (5-7 seconds), he was prodded with: "Say yes or no." The cards were shown until a response was made. This test was scored for hits and false-positive responses. Total testing time per patient was approximately 90 minutes with a retention interval of approximately 60 minutes between the Selective Reminding and Word Recognition Tests.

The word order in each Selective Reminding Test was randomized for each individual subject. The presentation of each Selective Reminding Test (HF/HI versus LF/LI) and each Word Fluency Test (letters versus category) was counterbalanced. Otherwise, all other conditions were kept constant.

STATISTICAL ANALYSIS

The words chosen as stimuli for the Selective Reminding Test were rated for frequency of use in the language (Kucera and Francis, 1967). Two Selective Reminding Tests were established using these ratings: High Frequency/High Imagery (HF/HI) words and Low Frequency/Low Imagery (LF/LI) words. The high frequency words appear highly imagable, while the low frequency words appear less imagable. However, no formal ratings were available or computed.

The characteristics (frequency and imagery) described above were then matched on a critical psychometric variable; that is, the 2 tests (HF/HI and LF/LI) were matched on true score variance (Chapman and Chapman, 1973, 1978). The term "true score" refers to the portion of an observed score that is replicable. The observed score consists of the true score plus the error of measurement. Errors of measurement may be due to variability in the subject's motivation, alertness, emotional state, cognitive state, luck in guessing, and changing test conditions. The variance of observed scores is the sum of the variances of the true scores and of errors of measurement. The variance of true scores should be smaller than the variance of observed scores.

This matching of subtests is especially crucial with groups of brain-injured patients where a generalized performance deficit can masquerade as a differential deficit if one of two subtests (HF/HI or LF/LI) measures a generalized deficit better than the other.

Take for example the case where test 1 has a large true score variance and test 2 has a small true score variance. The variance on test 2 is small because of the use of very easy items. Test 1 will yield a relatively large mean difference in true score between subjects of high ability and subjects of low ability. For test 2, the comparable mean difference will be smaller.

More specifically, a memory test that asks for recall of HF/HI words and LF/LI words might be constructed with the assumption that these two subgroups are uniquely sensitive to different severities of brain damage. Let us say that subtest 1 is composed of the LF/LI words and subtest 2 is composed of the HF/HI words. Irrespective of word rating characteristics, if subtest 1 (LF/LI words) is composed of middle-range items with a large true score variance and subtest 2 (HF/HI words) is composed of easy items with a small true score variance, then the larger difference in true score for test 1 does not mean that the more able and less able subjects differ more on ability 1 than ability 2, but instead reflects the fact that the test items were chosen so that test 1 has a greater true score variance than test 2 (Chapman and Chapman, 1973, 1978). The differential deficit in performance merely reflects the particular choice of items for the two tests, and not some basic difference in ability between the brain damaged and control groups. Thus, matching on true score variance is essential.

It should be clear that in order to insure true differential deficit in performance, it was necessary to match on true score variance. True score variance is the product of reliability and observed score variance. It will be greater when reliability and observed score variance are greater. Both the observed score variance and reliability are greater when the items are more numerous, more often fall in the middle range of difficulty, and tend to measure the same ability. It is also critically important to match on the shape of the distribution of item difficulty.

There are several problems that must be considered at this point. In texts that discuss this issue, most examples that describe matching on true score variance use tests that are not time dependent. That is, each item on such tests is answered without delay. A correct response on such an item is based on prior knowledge or facts related to that item. The resultant probability of answering that item or question relies upon rather "crystalized" processes.

In memory research, which is of course critically dependent upon "fluid" time characteristics, there is a variety of response curves with associated probabilities that depend upon list length and trial number. In addition, limits are necessarily placed upon total number of stimulus items due to attentional, memory, and experimental time constraints. Finally, the distribution of item difficulty may also be dependent upon serial position on the stimulus list; or upon word attributes such as frequency, imagery, and number of meanings.

Given these caveats, several precautionary steps were taken to reduce or prevent the likelihood of psychometric error (i.e., the error of not matching on true score variance). A normal sample (N=50) of subjects was obtained. These subjects received two Selective Reminding Tests, each one composed of a different subgroup (i.e., HF/HI or LF/LI).

Results showed the distribution of each Selective Reminding Test (using probability of recall of each item for the first trial of each test) to be similar as was the true score variance (HF/HI = .00631; LF/LI = .00487). These steps were sufficient to insure that the two subtests (HF/HI and LF/LI) had a similar distribution (including similar true score variance) which was necessary in the case of assignment of differential deficit to two groups based on two test distributions.

For all hypotheses the independent variables are groups, (right cortically lesioned, left cortically lesioned, and controls). The level of significance for all statistical analyses was set at $p<.05$. For Hypothesis #1, the dependent variables are total list recall, long term storage, long term retrieval and consistant long term retrieval. Adjacent trials will be blocked, permitting five scores per dependent variable per subject. This will insure that any trend in recall or storage over trials will have to be marked in order to reach levels of significance. Statistical analyses will be by repeated measures ANOVA on one factor (trials). If a significance level is reached for the between subjects condition, post hoc analyses will be by simple F tests and the Tukey (A) Test.

For Hypothesis #2, the dependent variables are the same as for Hypothesis #1. Statistical analysis will be by within group T-tests comparing percent correct high frequency and low frequency scores on all retrieval and storage measures.

For Hypothesis #3, the dependent variables are fluency output for letters and categories,and total fluency (category + letters). Three one-way ANOVAS will be computed. If a significance level is reached for the between group condition, post hoc analyses will be computed utilizing the Tukey (A) Test. Pearson-Product moment correlations will be computed on individual scores for fluency output and first trial total recall scores for each (HF/HI and LF/LI) Selective Reminding Test to evaluate similarity in retrieval processes.

For Hypothesis #4, the dependent variable is d', a signal detection measure that indicates the subject's ability to discriminate correct from incorrect responses on the word recognition test. Statistical analysis will be by a one-way ANOVA. If significant differences between groups are found for the d' condition, post hoc analysis will be computed utilizing Tukey's Test.

For Hypothesis #5, the dependent variables will be total number of hits and error types (phonemic, semantic, random) and the ratio score of phonemic to semantic errors per group. Statistical analysis will be by a one-way ANOVA. If significant differences between groups are found, post hoc analyses will be computed utilizing Tukey's Test.

For Hypothesis #6, the dependent variables will be the number of combined hits and false-positive responses, geometric design hits and false-positive responses and nonsense design hits and false-positive responses. Statistical analysis will be by a one-way ANOVA. In addition, a d' analysis on combined hits and false-positive responses will be computed to measure the subject's ability to discriminate correct from incorrect responses on the recurring figures test. If significant differences between groups are found for the d' condition, post-hoc analyses will be conducted utilizing Tukey's Test.

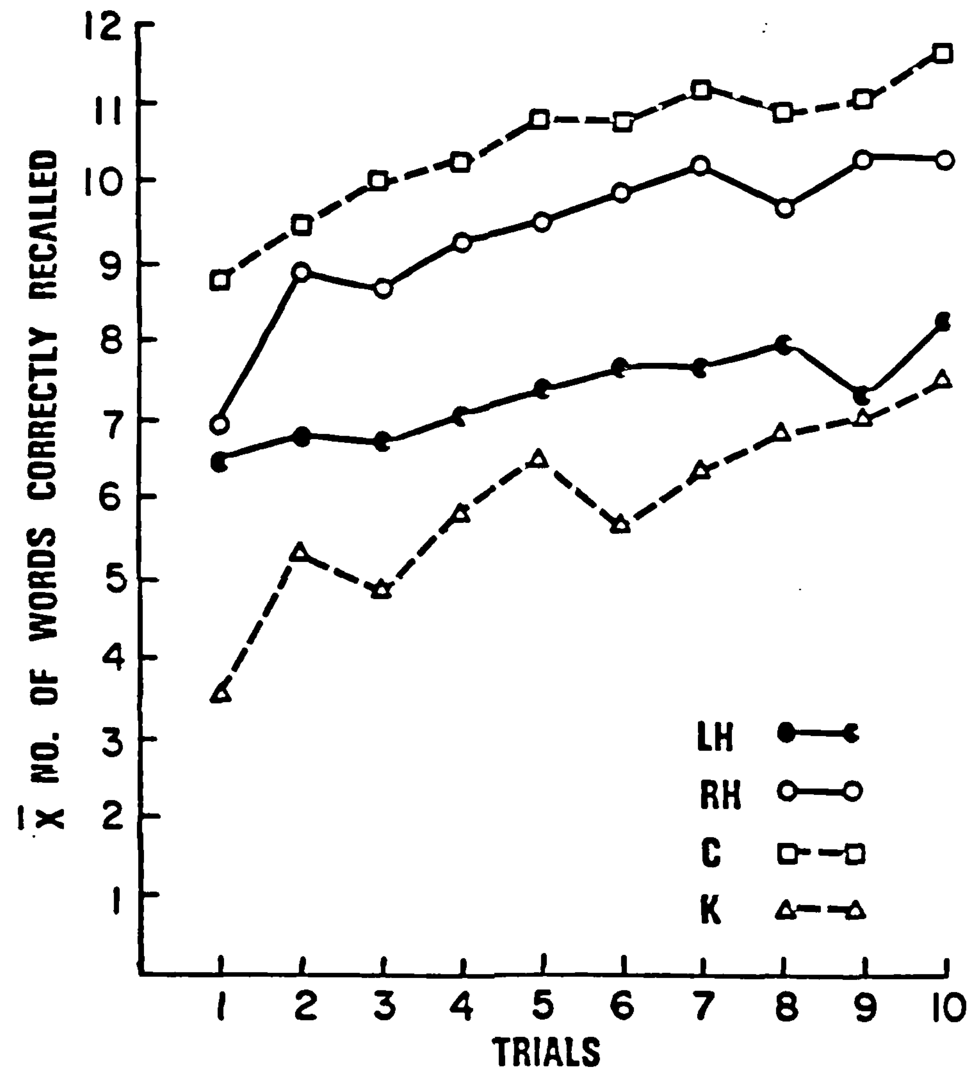
VI. RESULTS

SELECTIVE REMINDING TEST

High Frequency/Imagery Words

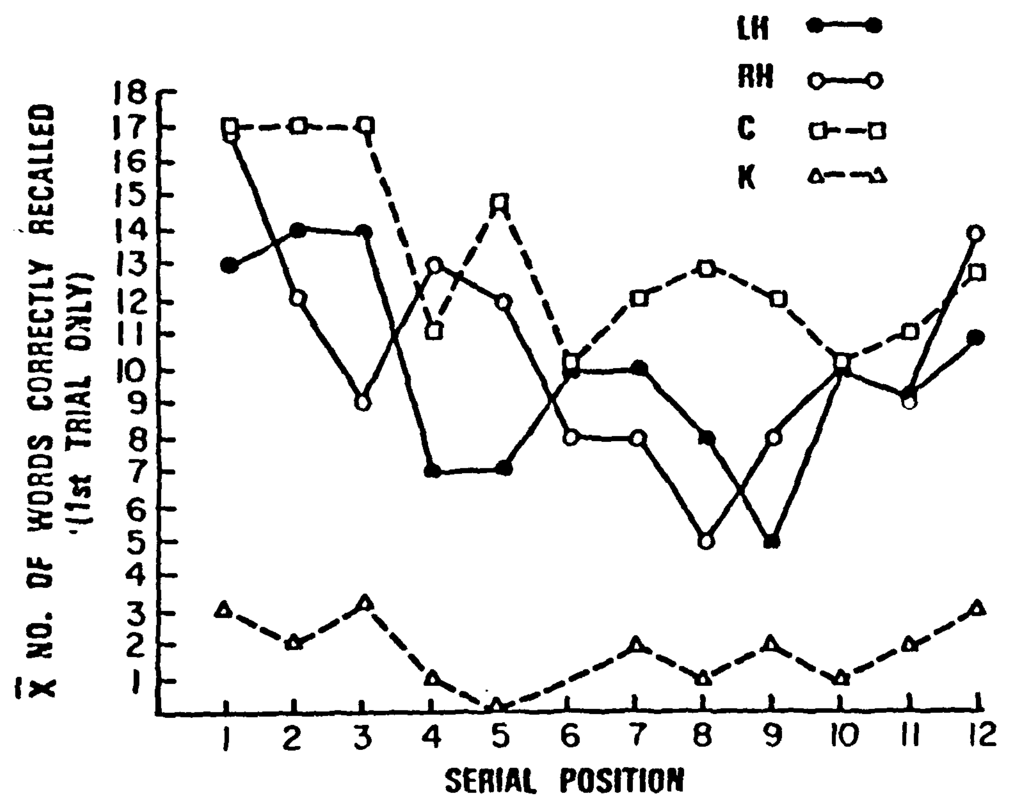
1. Total Recall.

The main effects of conditions ($F(2,51)=12.55$, $P<.001$), trials ($F(4,204)=43.51$, $P<.001$), and trials by conditions ($F(8,204)=3.41$, $P<.001$) were all highly significant. Therefore, F-tests for simple effects were computed and when levels of significance were reached, post-hoc analyses were computed with Tukey's Test. Computation of simple F-tests for the trial by group interaction revealed no significant differences in slope (i.e., learning rates) over the blocked trials between the controls and right cortically lesioned group or between the controls and left cortically lesioned group. However, a significant difference in slope was found between the right and left cortically lesioned groups ($F(4,204)=3.12$, $P<.05$). This difference can be seen in Figure 1. A simple F-test for the trials effect (i.e., for a significant improvement in recall noted over blocked trails) in each group was then computed. Significance at the $P<.001$ level was reached for all groups with the control ($F(4,204)=20.64$) and right cortically lesioned groups ($F(4,204)=22.63$) achieving greater performance change than the left cortically lesioned group ($F(4,204)=7.24$). While there was no significant difference in overall recall performance between the control and right cortically lesioned groups, both groups' recall performances were significantly



TOTAL RECALL – HIGH FREQUENCY/IMAGERY WORDS

FIGURE 1



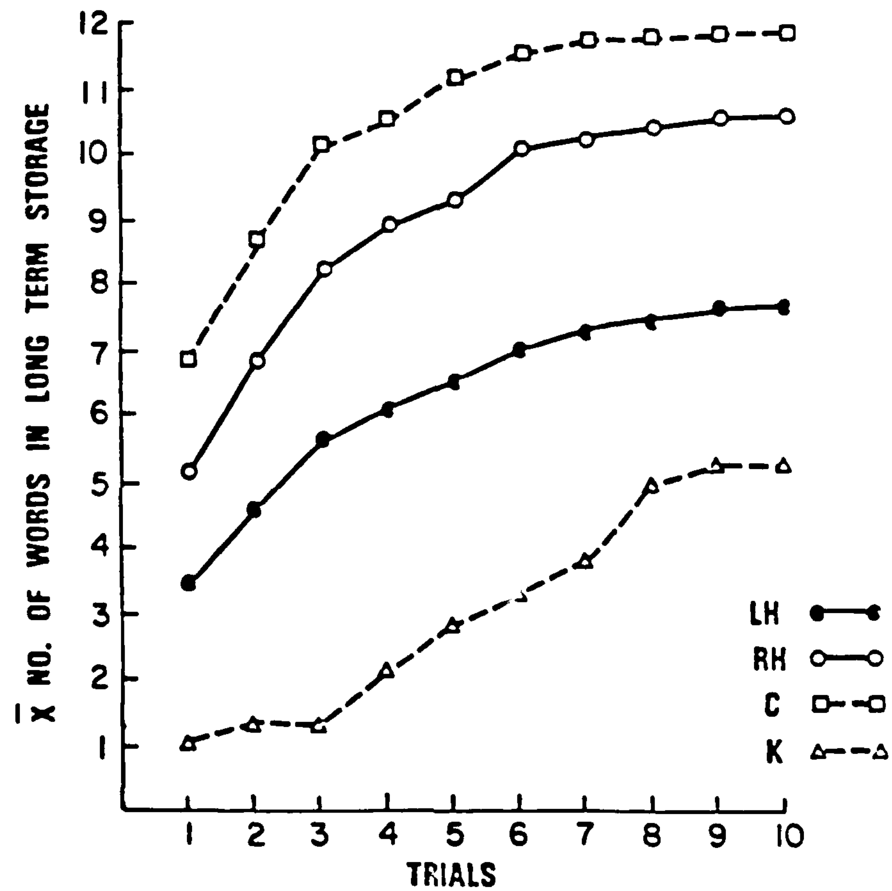
SERIAL POSITION CURVES: HIGH FREQUENCY/IMAGERY WORDS

FIGURE 2

(Tukey Test, $P<.01$) superior to the left cortically lesioned group. Figure 1 illustrates that while both the control and right cortically lesioned groups' recall scores approached ceiling levels over the 10 trials, the left cortically lesioned group only achieved small gains in recall performance despite a recall total similar to the right cortically lesioned group on trial 1. Figure 2, which displays the $\overline{X}$ serial position curves for trial 1, is not particularly helpful in illustrating why the left cortically lesioned group was unable to profit from selective reminding as much as the right cortically lesioned group. An interesting finding, not subject to statistical analysis, can be seen in Figure 1. The Korsakoff group's learning curve appears similar to those of the control and right cortically lesioned groups, and by the last 2 trials, the Korsakoff group is recalling nearly as many high frequency/imagery words as the left cortically lesioned group. This observation supports the recent findings that suggests if Korsakoff patients are given enough practice, they are able to evidence at least some learning (Huppert and Piercy, 1978).

2. Long Term Storage, Consistent Retrieval, and Long Term Retrieval.

Figure 3 reveals that by the 10th trial of the Selective Reminding Test, the control group was able to encode 99% of the high frequency/imagery words into long term storage, the right cortically lesioned group was able to encode 88% of the high frequency/imagery words into long term storage, the left cortically lesioned group was able



LONG TERM STORAGE – HIGH FREQUENCY/IMAGERY WORDS

FIGURE 3

to encode 64% of the high frequency/imagery words into long term storage, while the Korsakoff group managed to encode only 42% of the high frequency/imagery words into long term storage. The main effects of trials ($F(4,204)=124.30$, $P<.001$) and groups ($F(2,51)=10.15$, $P<.001$) were highly significant. The trial by groups interactions did not reach significance indicating that all groups encoded into long term store at similar rates. Simple F-tests for within group increases in encoding performance across trials were all highly significant (Control: $F(4,204)=43.32$, $P<.001$; Right Cortically lesioned: $F(4,204)=50.86$, $P<.001$; Left Cortically lesioned: $F(4,204)=31.62$, $P<.001$). Comparison by Tukey test for overall number of words encoded into long term storage revealed no significant differences between the control and right cortically lesioned groups, while both these groups encoded significantly more words into long term storage than the left cortically lesioned group (RH-LH=2.68, $P<.05$; C-LH=4.26, $P<.01$). This finding suggests that at least part of the reason for the left cortically lesioned group's inability to recall as many words as the control or right cortically lesioned groups was because of the inability to encode words into long term storage (as judged by the necessity to remind the left cortically lesioned group of 46% of the high frequency/imagery words every trial). Figure 3 also shows that the Korsakoff group was not as successful as the left cortically lesioned group at encoding high frequency/imagery words into long term storage despite achieving similar recall rates on late trials of the Selective Reminding Test. This observation suggests that the Korsakoff group was able to utilize what words they had encoded into long term store as opposed to the left cortically lesioned group whose retrieval appears much more inconsistent, essentially under utilizing their long term store.

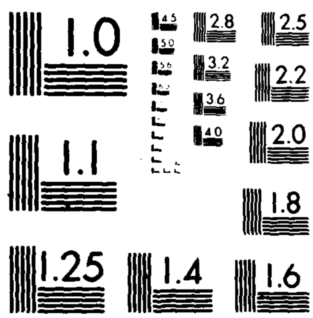
Figure 4 shows the number of high frequency/imagery words consistently retrieved for each group. The main effects of groups ($F(2,51)=9.91$, $P<.001$), trials ($F(4,204)=106.06$, $P<.001$) and the trial by group interaction ($F(8,204)=2.78$, $P<.05$) were all significant. Simple F tests showed that the control and right cortically lesioned groups were able to consistently retrieve high frequency/imagery words at similar rates, but both groups consistently retrieved at a significantly different rate ($P<.025$) than the left cortically lesioned group. As in the case of total recall, the Korsakoff group resembled the left cortically lesioned group by the last few trials in their ability to consistently retrieve items. Tukey Test analysis of between group differences showed that there was no significant difference between the control and right cortically lesioned groups' ability to consistently retrieve items, although both groups (RH-LH, $P<.05$; C-LH, $P<.01$) consistently retrieved more items than the left cortically lesioned group. Simple F-tests showed all groups to have highly significant increases ($P<.001$) in consistent retrieval of high-frequency/imagery words across trials.

Figure 5 indicates the number of words retrieved (consistently + inconsistently) from long term storage for each group for each trial. The main effects of groups ($F(2,51)=12.23$, $P<.001$), trials ($F(4,204)=34.63$, $P<.001$), and trial by groups ($F(8,204)=227$, $P<.05$)

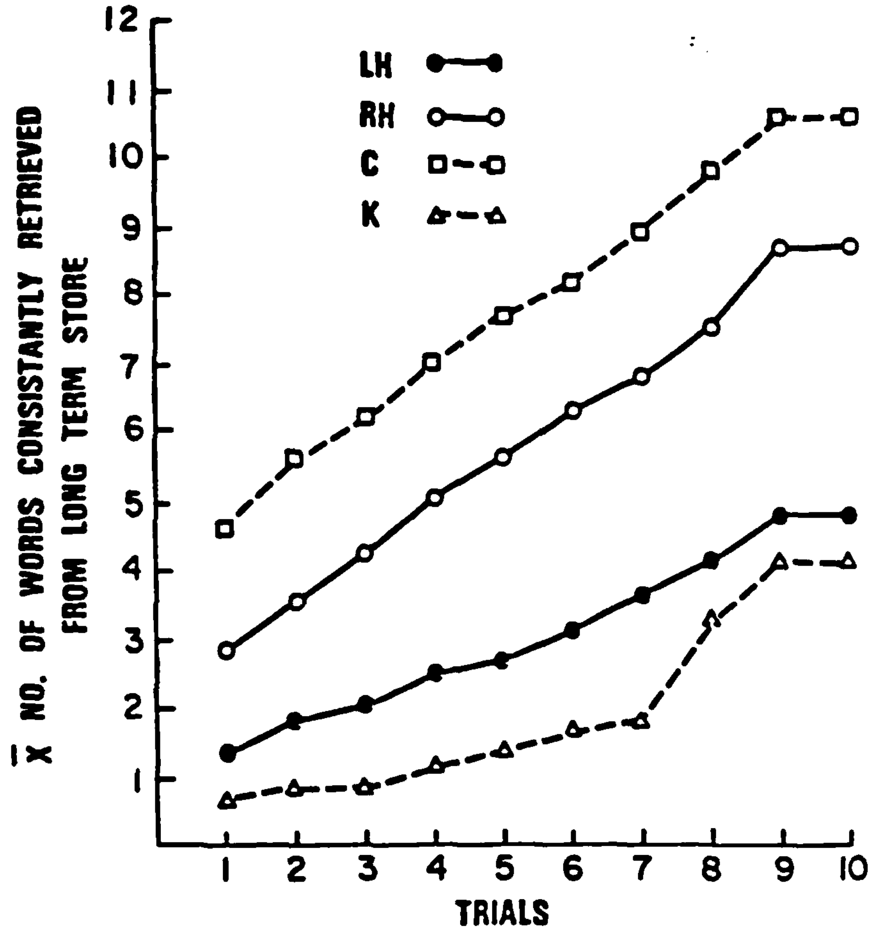
AD-A107 258 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH F/G 6/5
LONG AND SHORT-TERM MEMORY PROCESSES IN CORTICALLY DAMAGED PATI--ETC(U)
1981 J GRAFMAN
UNCLASSIFIED AFIT-CI-81-54D NL

2 of 2

END
DATE
FILMED
DTIC

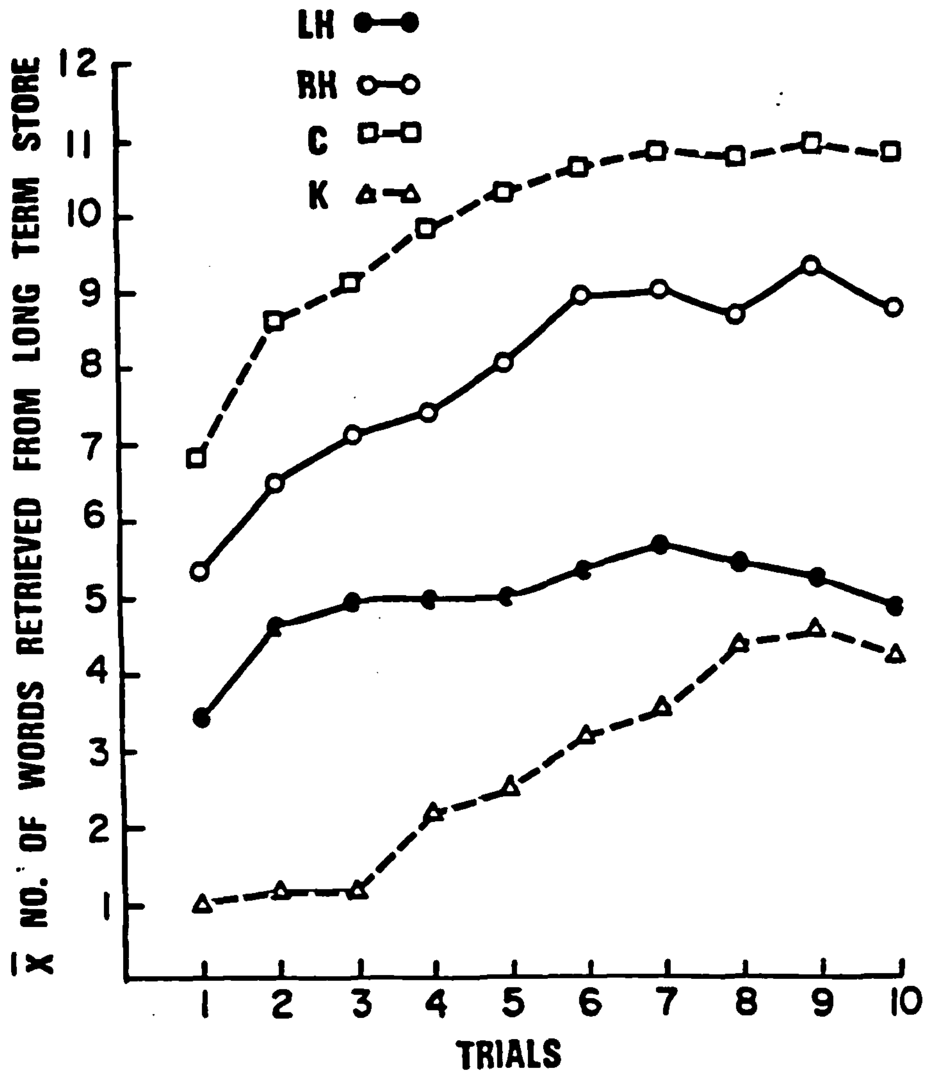


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



CONSISTANT RETRIEVAL – HIGH FREQUENCY/IMAGERY WORDS

FIGURE 4



LONG TERM RETRIEVAL – *HIGH* FREQUENCY/IMAGERY WORDS

FIGURE 5

were all significant. Simple F-tests showed that the control and right cortically lesioned groups retrieved words from long term storage at a similar rate while both groups significantly differed (controls-$F(4,204)=3.24$, $P<.05$; right hemisphere-$F(4,204)=3.87$, $P<.025$) from the left cortically lesioned group. Analyses by Tukey Test revealed that there were no differences between the control and right cortically lesioned groups for overall $\overline{X}$ number of words retrieved from long term store, while both groups differed significantly ($P<.01$) from the left-hemisphere lesion group. Interestingly, the left cortically lesioned group showed a decrease in retrieval from long term store over the last few trials, in what appears as a proactive inhibitory effect that only functions dramatically in the left cortically lesioned group.

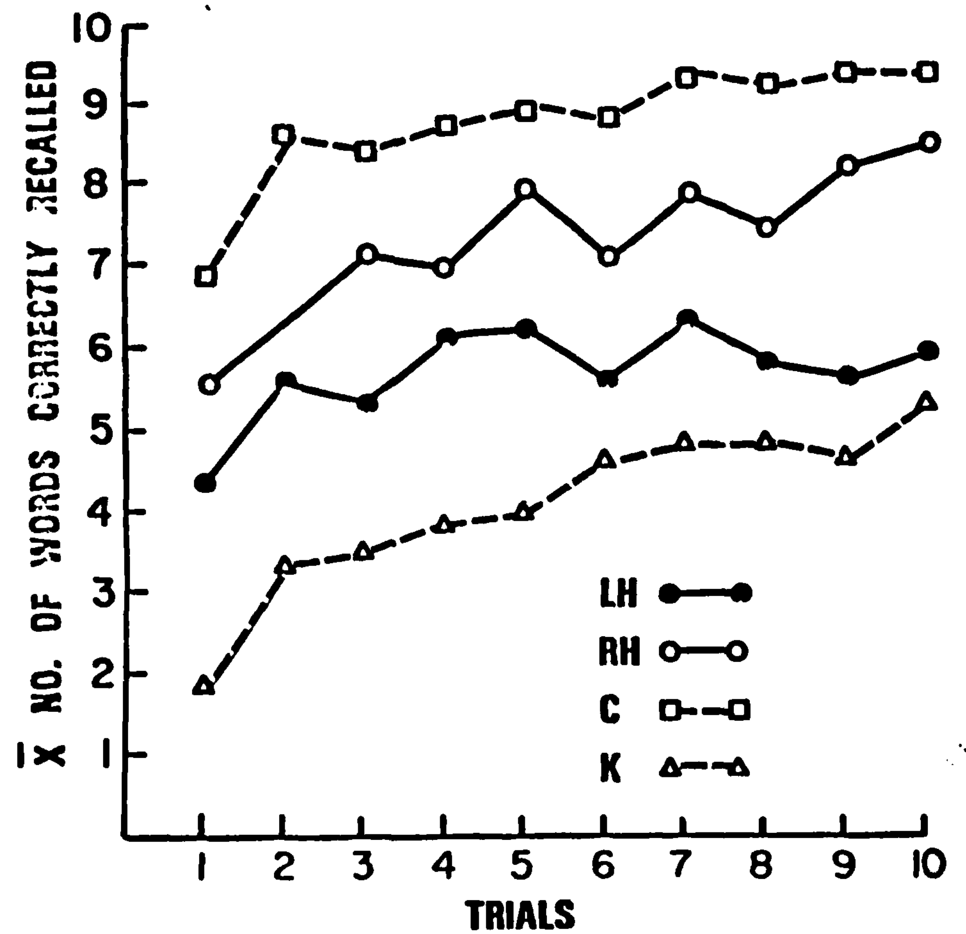
3. Summary.

The above results suggest that at least for high frequency/imagery words, subjects with left cortical lesions show impaired recall and retrieval processes when compared to both control and right cortical lesion groups whose retrieval performances are quite similar and show marked improvement over trials. Not only did the left cortically lesioned group show a smaller increase in performance over trials on all measures, but indeed showed different slopes for those measures. Surprisingly, by the late trials, the Korsakoff group demonstrated $\overline{X}$ recall and retrieval levels that appeared similar to the left cortically lesioned group. Although the Korsakoff group was not able to encode as many words into long term store, they could retrieve as many as the left cortically lesioned group. The results of the Selective Reminding Test utilizing low frequency/imagery words are presented below.

Low Frequency/Imagery Words

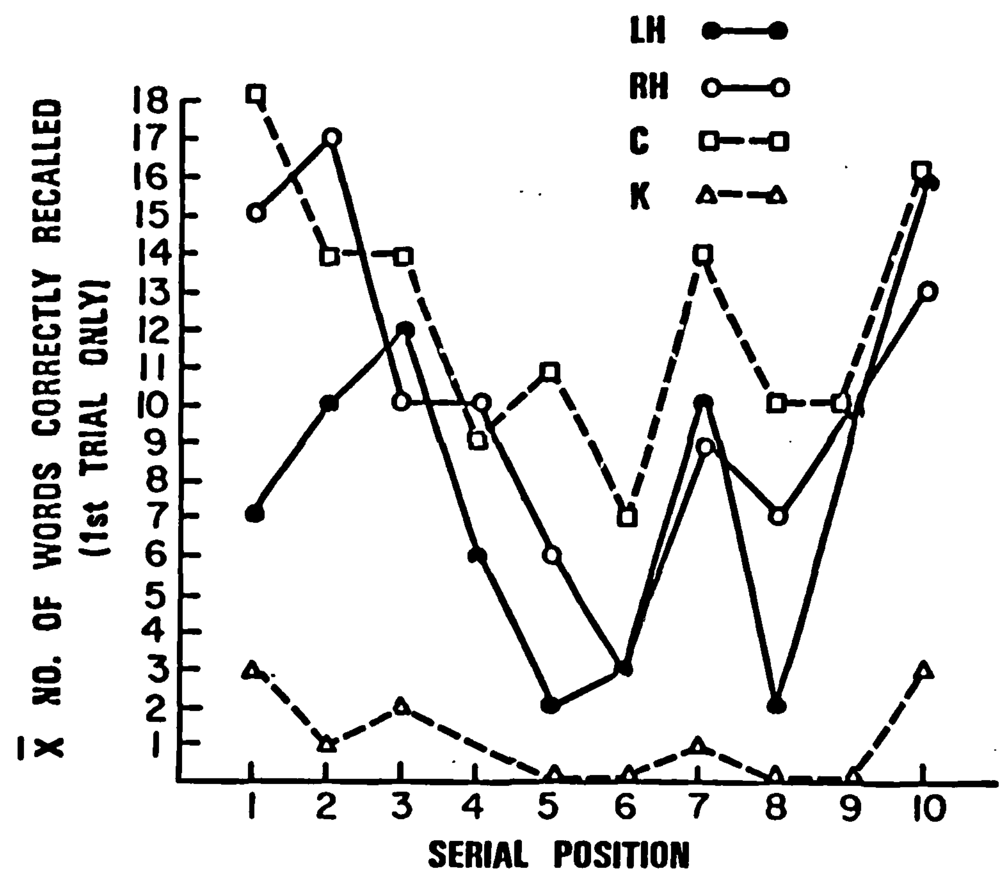
1. Total Recall (See Figure 6).

For total recall, the main effect of groups was highly significant ($F(2,51)=41.46$, $P<.001$), but the main effects for trials and trials by conditions did not reach significance. A Tukey Test analysis comparing overall group performances found all groups to be significantly different ($P<.01$) from each other. A significant difference was maintained over the trial block comparisons although the performance levels of the right cortically lesioned and control groups became closer over trials (trial blocks: 1-$P<.01$; 2-$P<.01$; 3-N.S.; 4-$P<.05$; 5-$P<.05$). The Korsakoff group appears to show a significant increase in recall over trials and by the last few trials their performance is similar to the left cortically lesioned group. Figure 7 illustrates the serial position curves from trial 1 of this task averaged over subjects in each group. Three aspects of Figure 7 stand out: the depressed recall for initial serial positions and for serial position 8 (which comes in the so-called "recency portion" of the curve) for the left cortically lesioned group and the overall relative flatness of the serial position curve for the Korsakoff group. The position effects seen in the left cortically lesioned group suggest difficulty either in encoding verbal stimuli into long term



TOTAL RECALL — LOW FREQUENCY/IMAGERY WORDS

FIGURE 6



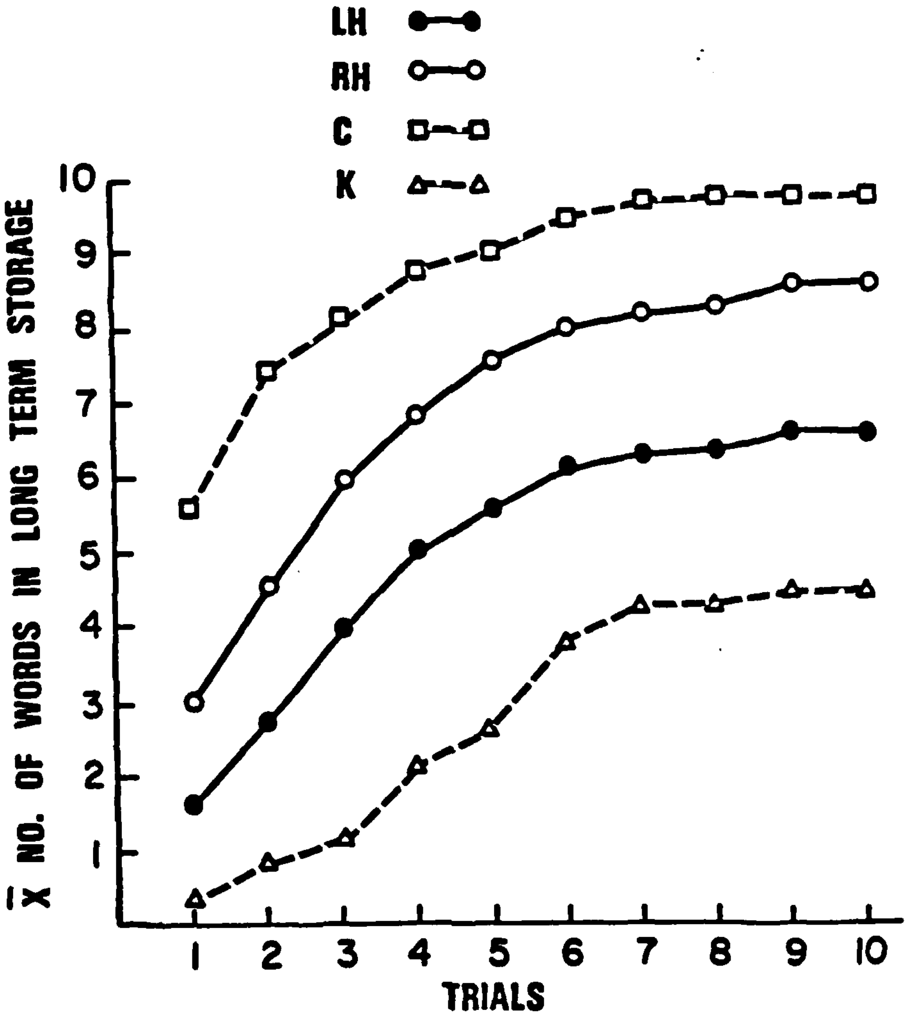
SERIAL POSITION CURVES:
LOW FREQUENCY/IMAGERY WORDS

FIGURE 7

storage or in rapid processing of such stimuli (which could cause the position effects due to ineffective allocation of attention in rehearsal of words).

2. Long Term Storage, Consistent Retrieval, and Long Term Retrieval.

Following the analysis of total recall for low frequency/imagery words, a componential analysis was again undertaken. Figure 8 illustrates the $\overline{X}$ number of words encoded into long term storage by a particular trial. The main effects of groups ($F(2,51)=12.74$, $P<.001$), trials ($F(4,204)=191.35$, $P<.001$), and trials by groups ($F(8,204)=2.37$, $P<.05$) were all significant. Simple F tests showed that the control and right cortically lesioned groups encoded low frequency/imagery words into long term storage at different rates. This difference appears due to the steeper slope evidenced in the right cortically lesioned group. No other group by trial comparisons were significant. Tukey Test comparison for overall group encoding differences revealed all groups to be significantly different in performance (C-RH=$P<.05$; RH-LH=$P<.05$; C-LH=$P<.01$). Simple F tests demonstrated a highly significant improvement over trials for the control ($F(4,204)=39.98$, $P<.001$), right cortically lesioned ($F(4,204)=84.62$, $P<.001$) and left cortically lesioned ($F(4,204)=71.48$, $P<.001$) groups. The striking finding here is the relatively similar slopes and the positional relationship between groups. The right cortically lesioned group begins the task encoding low frequency/imagery words into long term storage at a performance rate similar to the left cortically lesioned

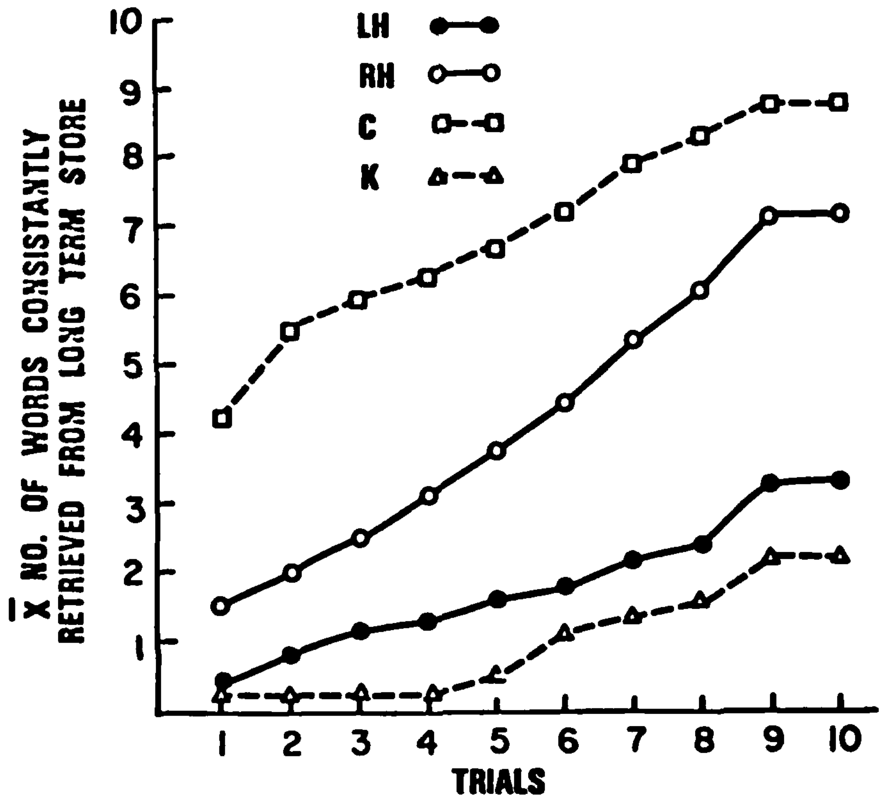


LONG TERM STORAGE – LOW FREQUENCY/IMAGERY WORDS

FIGURE 8

group, but eventually performing at a level more similar to the control than the left cortically lesioned group. While the left cortically lesioned group is clearly able to encode more low frequency/ imagery words into long term storage than the Korsakoff group, this difference is not apparent in terms of total recall performance (see above).

Figure 9 illustrates the $\overline{X}$ number of low frequency/imagery words consistently retrieved from long term store for each group over the 10 trials. The main effects of groups ($F(2,51)=19.56$, $P<.001$), trials ($F(4,204)=100.02$, $P<.001$), and the trials by groups interaction term ($F(8,204)=4.79$, $P<.001$) were all significant. Simple F tests revealed that the right cortically and left cortically lesioned groups consistently retrieved items from long term store at significantly different rates ($F(4,204)=9.11$, $P<.001$). No other comparisons were significant. Tukey Test comparisons for overall differnces in consistent retrieval performance were highly significant ($P<.01$) for all between group comparisons. In addition, simple F-Test analysis for within group performance change over trials indicates that the control ($F(4,204)=32.61$, $P<.001$), right cortically lesioned ($F(4,204)=62.88$, $P<.001$), and left cortically lesioned ($F(4,204)=14.10$, $P<.001$) groups all showed highly significant improvement in consistent retrieval over trials. There are 2 major findings of interest that can be seen in Figure 9: the right cortically lesioned group's performance approaches the control group's performance by the last few trials, and the Korsakoff group's ability to consist-



CONSISTANT RETRIEVAL – LOW FREQUENCY/IMAGERY WORDS

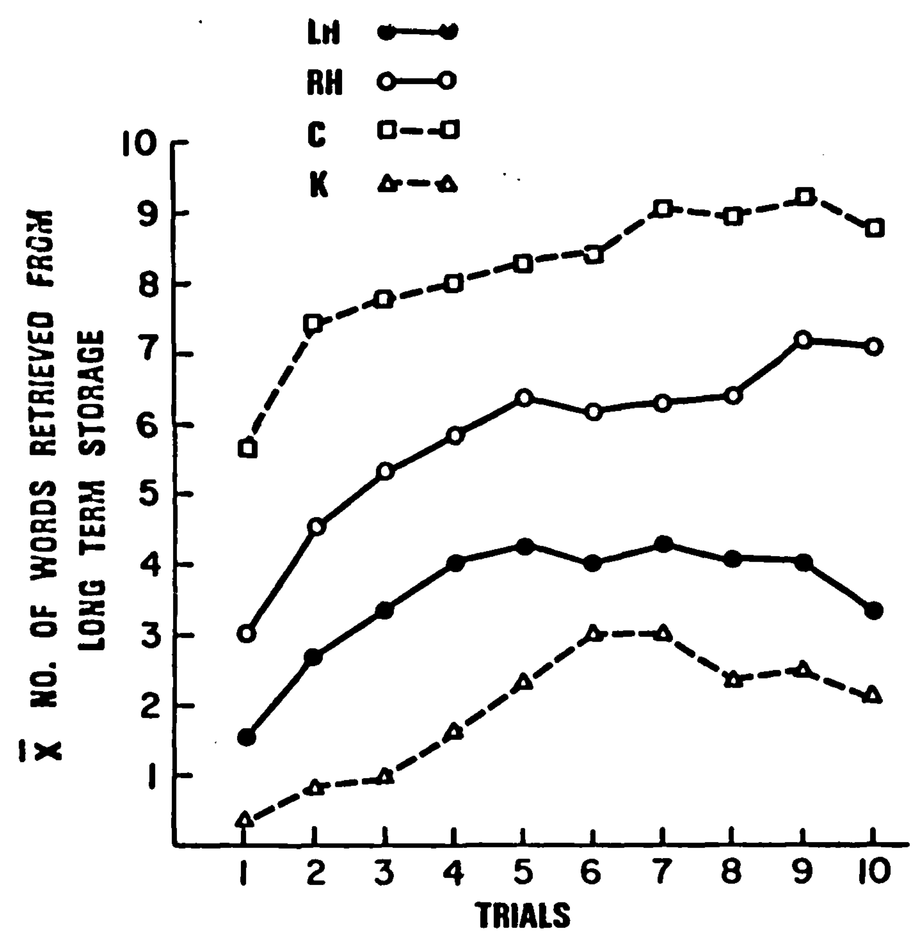
FIGURE 9

ently retrieve items from long term storage is similar to the left cortically lesioned group.

The final analysis (in this section of the Results Chapter) concerns the number of low frequency/imagery words retrieved (consistently + inconsistently) from long terms storage per trial block (see Figure 10). The main effects of groups ($F(2,51)=19.27$, $P<.001$) and trials ($F(4.204)=1040.08$, $P<.001$) were highly significant. The trials by group interaction term only approached significance ($F(4,204)=1.88$, $P<.10$). Tukey Test analysis for between group comparisons of overall retrieval level was significant ($P<.01$) for all comparisons. Simple F-Test analysis for change in retrieval performance as a function of trials was significant for the control ($F(4,204)=13.22$, $P<.001$), right cortically lesioned ($F(4,204)=21.07$, $P<.001$), and left cortically lesioned ($F(4,204)=8.71$, $P<.001$) groups. A Tukey Test analysis for within group trial block differences revealed that the left cortically lesioned group's retrieval performance significantly declined ($P<.01$) between trial block 4 (trials 7 and 8) and trial block 5 (trials 9 and 10). This finding suggests that particularly for the left cortically lesioned (and Korsakoff) group, there is a build up of proactive inhibition that can be seen only when long term retrieval is analyzed independently of total recall mechanisms.

3. Summary.

The above results suggest that for free recall of low frequency/imagery words, the left cortically lesioned group shows impaired



LONG TERM RETRIEVAL – LOW FREQUENCY/IMAGERY WORDS

FIGURE 10

recall, long term storage, and long term retrieval processes when compared to the right cortically lesioned and control groups. The right cortically lesioned group's performance tends to be similar to the left cortically lesioned group's performance during early trials, but approximates the control group's performance during later trials. The Korsakoff group's performance very closely approximates the left cortically lesion group's for recall, long term storage and retrieval, particularly during later trials.

Summary of Results from Selective Reminding Free Recall Task

The overall results suggest that the left-cortically lesioned group demonstrates impaired verbal learning, storage, and retrieval when contrasted with right cortically lesioned and control groups. While the right cortically lesioned group's storage and retrieval processes appear similar to the left cortically lesioned group for early trials, by the later trials the right cortically lesioned group's performance approaches that of the control group on most measures evaluated. The left cortically lesioned group is able to encode more words into long term storage than a group of Korsakoff patient's, but the left cortically lesioned group only seems able to retrieve a small portion of those words, while the Korsakoff group appears to be able to retrieve a greater proportion of those words they are able to encode into long term storage. The Korsakoff group was also able to demonstrate increased recall, storage, and long term retrieval across trials. Both the Korsakoff and left cortically lesioned groups were particularly affected by a proactive inhibitory effect for retrieval of items from long term storage. A statistical analysis (t-tests) was computed for the differential effects of high frequency/imagery versus low frequency/imagery words. Overall recall performance shows that there was not a striking effect of word frequency. Serial position curves did show that for the low frequency/imagery words, there was a depressed recall performance by the left cortically lesioned group for the initial serial positions which suggests difficulty in storing items in, or retrieving items from long term storage. The Korsakoff group's serial position recall was generally depressed creating a "floor effect" which makes interpretation difficult. Encoding items into long term storage increased across trials at similar rates for all groups for both low frequency/imagery and high frequency/imagery words. This same finding holds true for the measures of consistent retrieval from long term storage and long term retrieval. There was only a non-significant word frequency trend for $\bar{X}$ consistent retrieval and combined retrieval from long term storage particularly for the left cortically lesioned and Korsakoff groups with low frequency/imagery words being more difficult to <u>retrieve</u> from long term storage, despite relatively equivalent storage levels for the two groups. These observations deserve further research with appropriate experimental designs. The meaning of these results will be expanded upon in the Discussion section in conjunction with the other test results reported below.

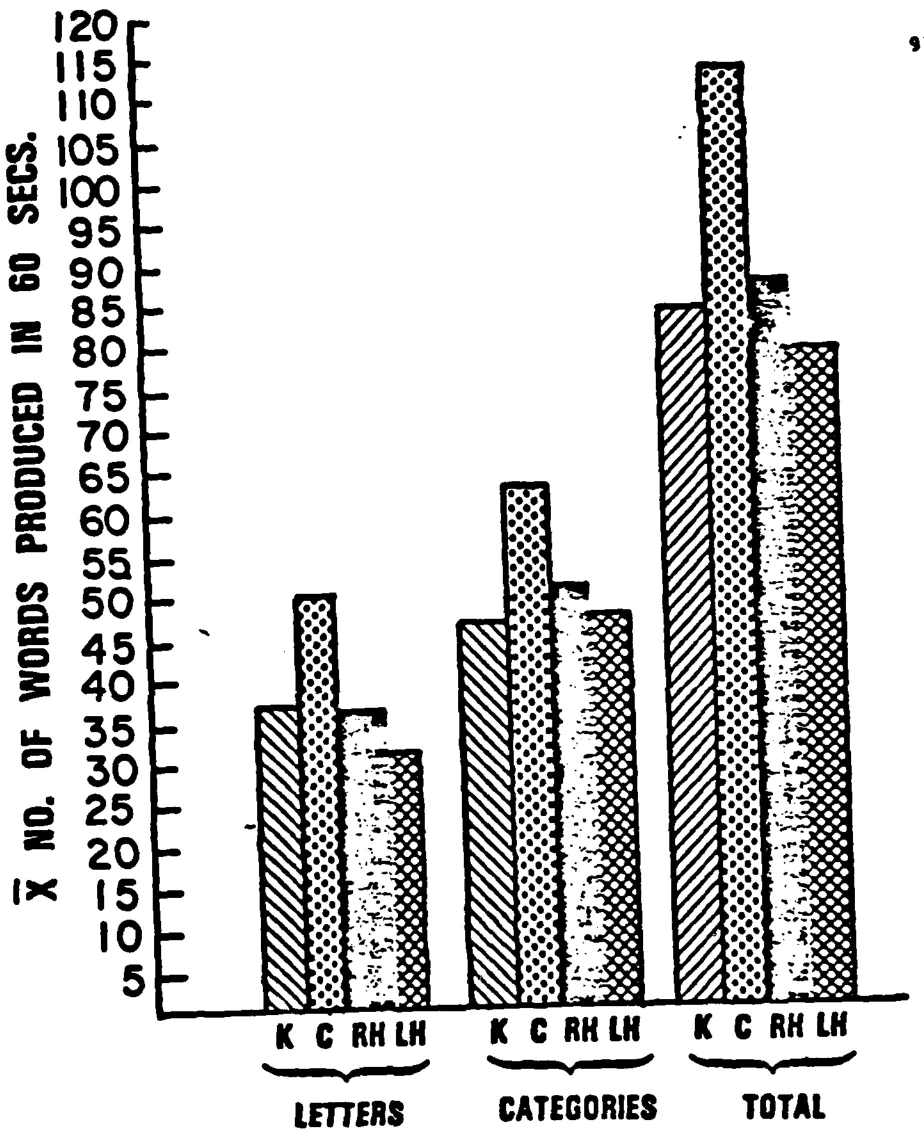
Word Fluency Task

1. Group Differences.

The between group comparisons for combined word fluency, letter fluency, and category fluency were analyzed by one-way ANOVAS. For the combined fluency (letters + categories) comparison, there was a significant main effect for the between groups condition ($F(2,51)= 9.32$, $P<.001$). Post-hoc analyses by Tukey Test revealed that while the control group fluency was significantly superior ($P<.01$) to both the right and left cortically lesioned groups, there was no significant difference in combined fluency between the lesion groups. The Korsakoff group performed at a level comparable to those of the lesion groups (see Figure 11).

Figure 12 illustrates each group's performance on the letter fluency task. A one-way ANOVA was significant ($F(2,51)=8.17$, $P<.001$) for the between groups condition. Analyses by Tukey Test again demonstrates the control group performance to be superior to both the right cortically ($P<.05$) and left cortically ($P<.01$) lesioned groups. Although the difference does not reach significance, the right cortically lesioned group is more fluent on this task than the left cortically lesioned group. In fact, the Korsakoff group also is more fluent than the left cortically lesioned group on this task.

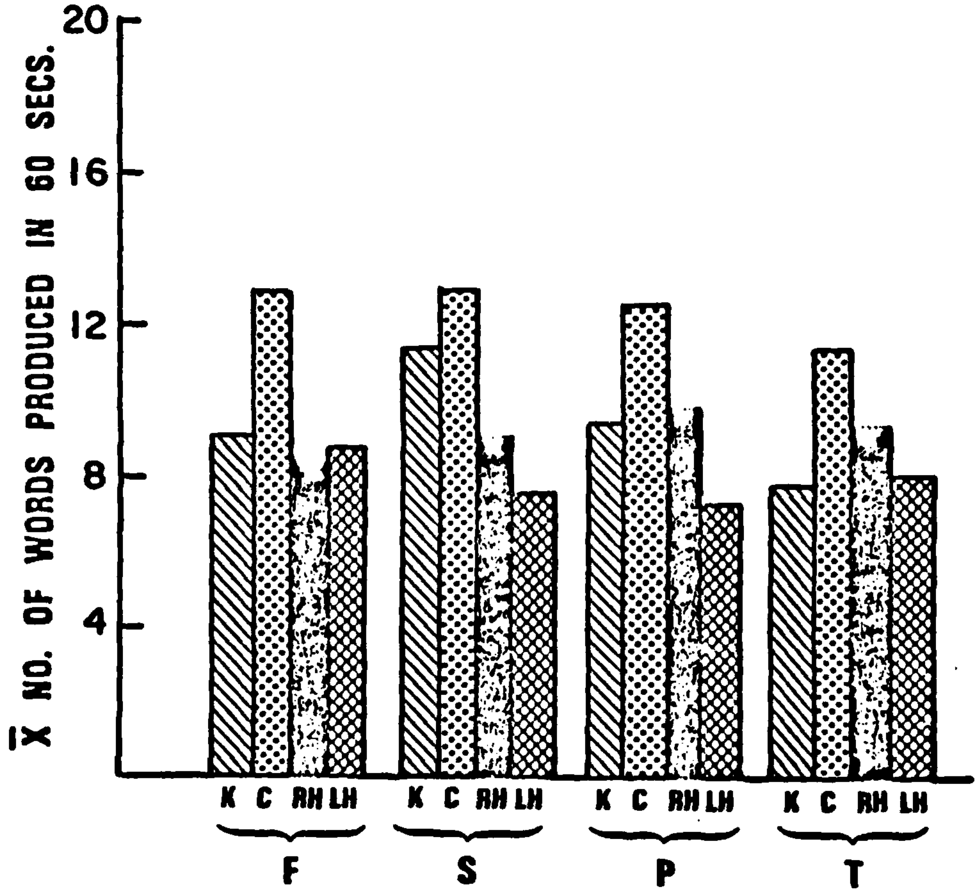
The last fluency task involved generation of members of a specific category (see Figure 13). A one-way ANOVA was significant ($F(2,51)=4.77$, $P<.025$) for the between groups condition. Post-hoc analyses by



STIMULUS CATEGORIES

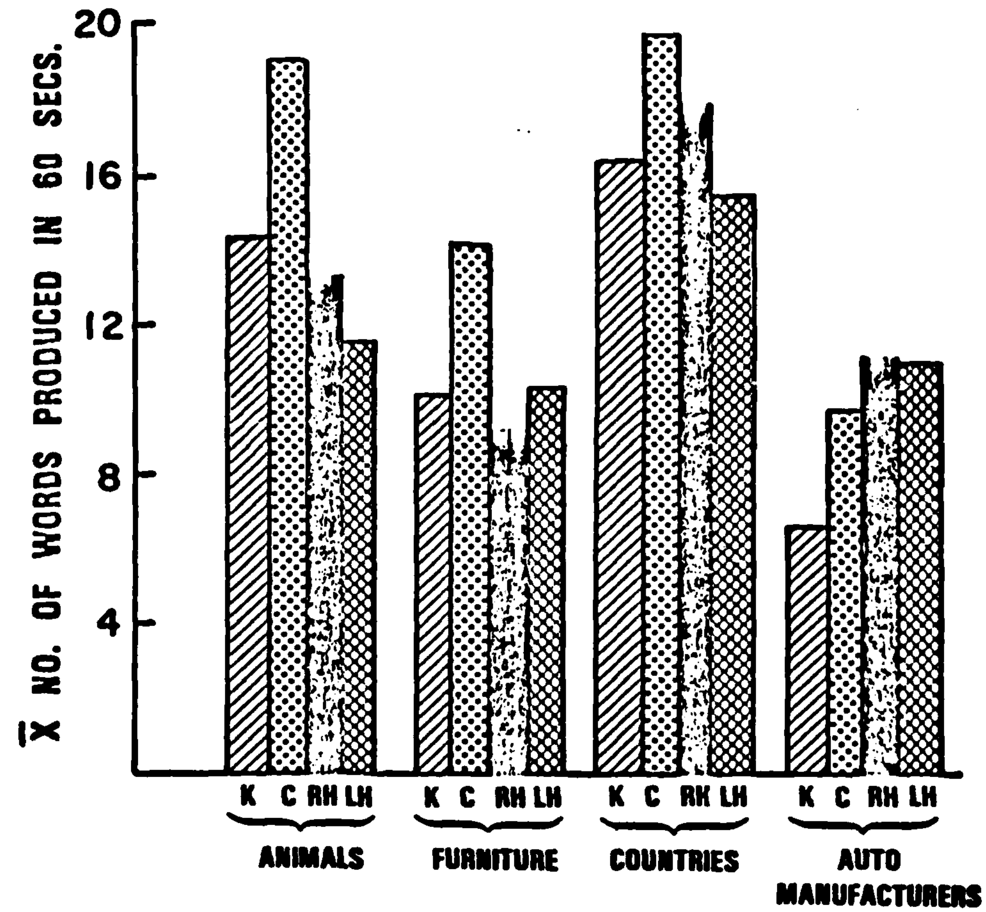
WORD FLUENCY TASK

FIGURE 11



WORD FLUENCY TASK — LETTER STIMULI

FIGURE 12



WORD FLUENCY TASK — CATEGORY STIMULI

FIGURE 13

Tukey Test revealed that only the control and left-cortically lesioned groups significantly differed ($P<.05$). The right cortically lesioned group does have a superior (but non-significant) category fluency when compared to the left cortically lesioned and Korsakoff groups.

In summary, across tasks the left cortically lesioned group's word fluency is significantly inferior relative to the control group. The left cortically lesioned group's performance is also inferior (but not significantly) to the right cortically lesioned group's performance. The right cortically lesioned group's word fluency is significantly inferior to the control group only on the letter fluency task. The Korsakoff group's performance is similar to the right cortically lesioned group on letter fluency, but similar to the left cortically lesioned group on category fluency. The group rankings on these tasks are similar to those found on the variables chosen for the selective reminding task. Since impaired or slowed retrieval may be a component of both fluency and recall tasks, Pearson Product correlations were computed to assess whether a relationship exists between the two tasks. These results are discussed below.

2. Correlational Analysis of Retrieval Processes.

Pearson Product correlations were computed between first trial total recall for high frequency/imagery words and low frequency/imagery words and total fluency, letter fluency, and category fluency (for the left cortically lesioned, right cortically lesioned and control groups) to ascertain if there is a relationship between performance on the two types of test.

Combined Fluency

The right cortically lesioned group's performance on the combined fluency measure was significantly correlated with both the high frequency/imagery ($r=.62$, $P<.01$) and low frequency/imagery ($r=.65$, $P<.01$) conditions. The left cortically lesioned group's performance was significantly correlated with only the high frequency/imagery condition ($r=.48$, $P<.05$), while the control group's performance was significantly correlated with only the low frequency condition ($r=.54$, $P<.05$).

Category Fluency

Again, the right cortically lesioned group's performance on the category fluency measure achieved significant correlations in both the high frequency/imagery ($r=.47$, $P<.05$) and low frequency/imagery ($r=.61$, $P<.01$) conditions. The left cortically lesioned group's performance did not achieve significant correlations with either condition. The control group's performance was significantly correlated with only the low frequency/imagery condition ($r=.51$, $P<.05$).

Letter Fluency

The right cortically lesioned group's performance on the letter fluency task achieved a significant correlation with both the high frequency/imagery ($r=.67$, $P<.01$) and low frequency/imagery ($r=.54$, $P<.05$) conditions. The left cortically lesioned group's performance on the letter fluency task was significantly correlated with the high frequency/imagery condition only ($r=.50$, $P<.05$). The control group's performance did not achieve correlational significance.

Summary of Results

The right cortically lesioned group achieved consistently significant correlations for both high frequency/imagery and low frequency/imagery words which, however, never accounted for more than 45% of the variance for any one correlation. Thus, while these correlations reached significance, they do not account for the majority of variance between the two performances measured. Nevertheless, the results reported above suggest that a significant albeit small proportion of the variance can be accounted for. Cautious interpretation of this finding would suggest that the right cortically lesioned group's depressed retrieval processes documented in both versions of the Selective Reminding Test and in the fluency tests reflect a common deficit. This deficit is interpreted as a resource allocation problem and not attributable to a specific verbal-linguistic impairment.

The left cortically lesioned group barely achieved significant correlations between combined and category fluency and the high frequency/imagery condition with no more than 25% of the variance being accounted for. Thus, even though the performance of the left cortically lesioned group was poor for both tasks, the reason for this group's poor performance on each task is probably different. This idea will be elaborated upon in the discussion.

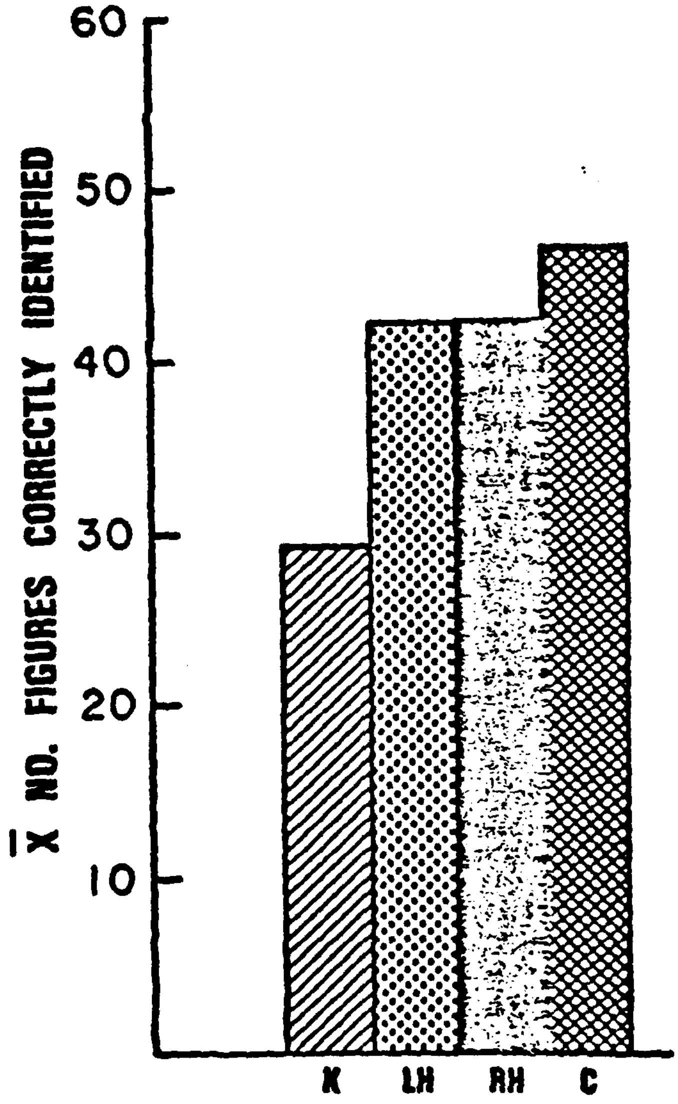
The control group's performance on combined and category fluency measures was significantly correlated with the low frequency/imagery condition. These correlations accounted for no more than 29% of the variance. This finding suggests that the control group's superior performances on all tasks subject to correlational procedures were due to largely independent processes. With respect to interpretation, the explanation for the control group's success is the same as that offered for the left cortically lesioned group's impairment; namely, separate cognitive processes. In contrast, the right cortically lesioned group's depressed performances seems due to a unitary process (as witnessed above) that overrides any individual cognitive processes that function in these two tasks and their various components.

RECURRING FIGURES TEST

The Recurring Figures Test was included in this experiment to prove that the anticipated left cortically lesioned group's verbal learning impairment was not merely due to a generalized cognitive deficit, but was the result of a specific verbal-memory deficit. Various components of the Recurring Figures Test were analyzed by one-way ANOVAS and, when appropriate, post-hoc tests (Tukey Test). In addition, a signal detection analysis was performed to ascertain if there were strategy or detection differences among the groups. The results are presented below.

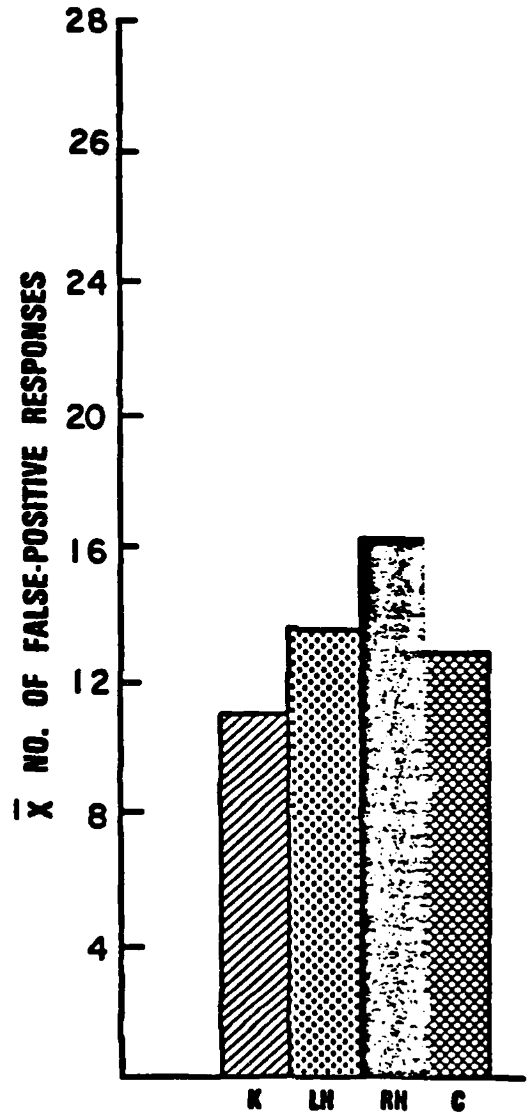
Combined Responses

One-way ANOVAS computed for total hits and total false-positives did not approach significance (see Figures 14 and 15). The left cortically lesioned group correctly identified as many figures as that of the right cortically lesioned group. Both group's hit levels



RECURRING FIGURES — TOTAL HITS
(GEOMETRIC + NONSENSE)

FIGURE 14



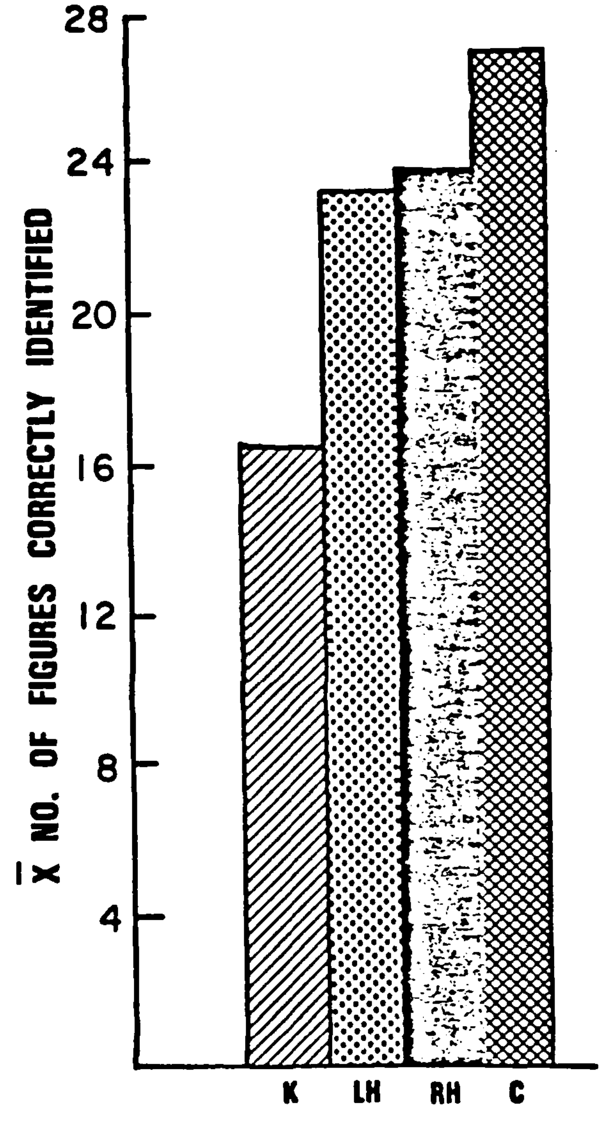
RECURRING FIGURES – TOTAL FALSE-POSITIVE RESPONSES (GEO. + NONS.)

FIGURE 15

were inferior to the hit level achieved by the control group. The Korsakoff group's hit level fell well below that of the experimental and control groups. While a statistical comparison of false-positive responses across groups did not approach significance, Figure 15 reveals a tendency for the right cortically lesioned group to commit more false-positive errors than the left cortically lesioned group, who in turn committed more false-positive errors than the control group. Surprisingly, the Korsakoff group committed the fewest number of false-positive errors. A more detailed analysis was then undertaken to assess the contribution of geometric design and nonsense design recognition performances to the combined score performances described above.

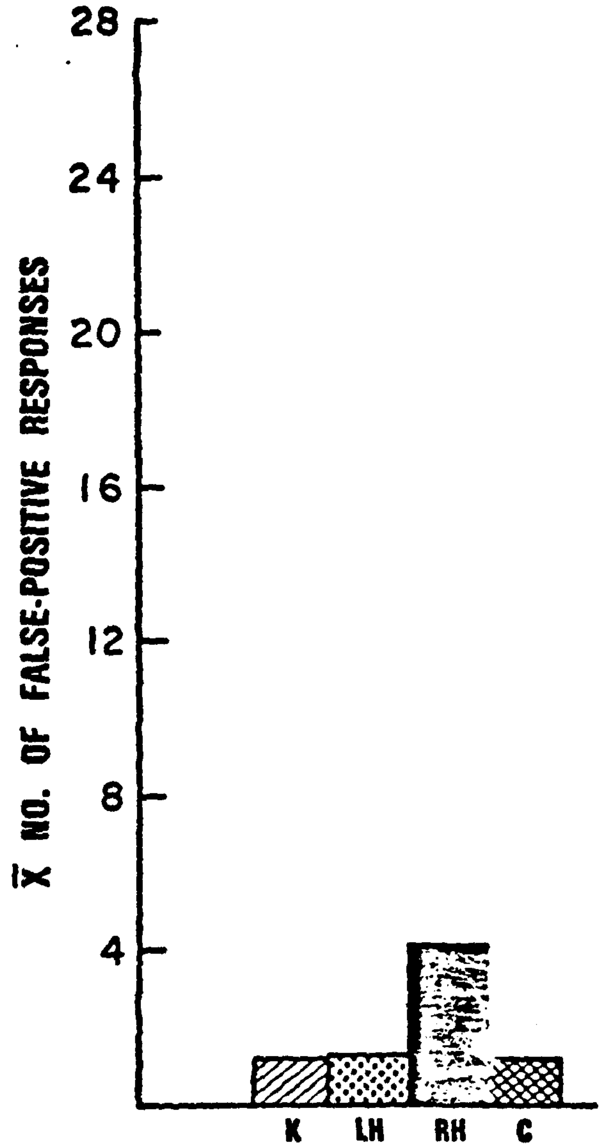
Geometric Designs (See Figure 16)

There were no significant differences between groups for $\overline{X}$ number of geometric figures correctly identified. However, a one-way ANOVA for $\overline{X}$ number of false-positive errors (see Figure 17) for geometric designs was highly significant ($F(2,51)=7.81$, $P<.01$). Post-hoc analyses by Tukey's Test revealed the right cortically lesioned group to have made significantly more false-positive errors than either the left cortically lesioned group ($P<.01$) or the control group ($P<.01$). Figure 16 *does* illustrate a nonsignificant tendency for the control group to have better $\overline{X}$ hit scores than either the right or left cortically lesioned groups whose performances are alike. The Korsakoff group's performance is substantially inferior to that of the other groups. For the false-positive error analyses,



RECURRING FIGURES – TOTAL HITS
(GEOMETRIC DESIGNS)

FIGURE 16



RECURRING FIGURES = FALSE-POSITIVE RESPONSES
(GEOMETRIC DESIGNS)

FIGURE 17

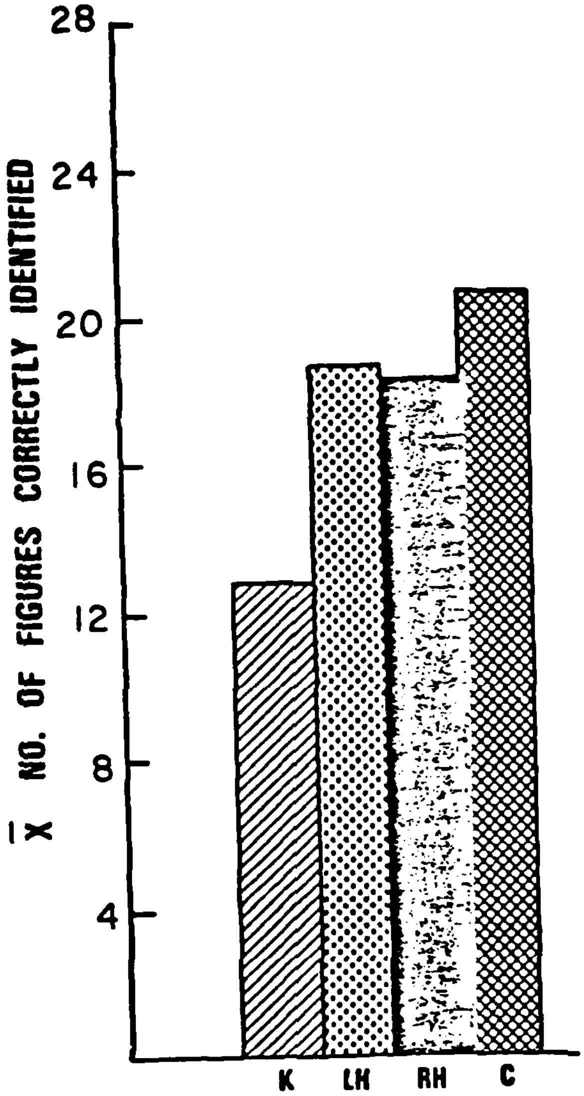
while the right cortically lesioned group demonstrated a significant proclivity towards comitting false-positive errors, it can be seen in Figure 17 that the remaining groups $\bar{X}$ false-postive response levels were quite low, effectively creating *a floor* effect that does not allow for interpretation of intergroup comparisons. The remaining analysis is for nonsense designs.

Nonsense Designs

One-way ANOVAS for both correct and false-positive responses did not reach significance. Figure 18 shows the $\bar{X}$ number of nonsense designs correctly identified. The control group's performance is slightly superior to both experimental groups' performances, whose performances are strikingly superior to the Korsakoff group's performance. Figure 19 shows the control and experimental groups' false-positive error levels to be similar, but once again, the Korsakoff group tends to commit fewer false-positive errors than the other groups.

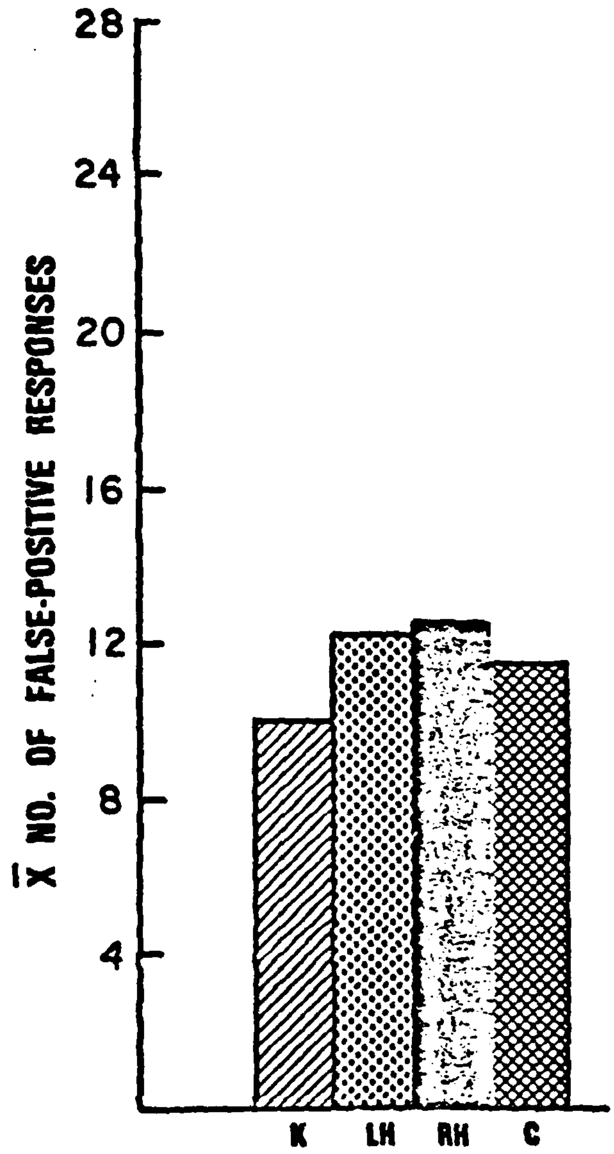
Signal Detection Analysis for Combined (Geometric + Nonsense)

A signal detection analysis was undertaken to see if there were any differences between groups in the strategy or detection components of the response process. d' and β scores were computed. Following log transformation (to achieve homogeneity of variance), the scores were subject to one-way ANOVAS. No significant differences for d' (sensitivity) or β (criterion level) between groups emerged. Both the control (β=1.54) and left cortically lesioned (β=1.85)



RECURRING FIGURES – TOTAL HITS
(NONSENSE DESIGNS)

FIGURE 18



RECURRING FIGURES = FALSE-POSITIVE RESPONSES
(NONSENSE DESIGNS)

FIGURE 19

groups tend to be more cautious (i.e., have a higher criterion for correct identification of designs) than the right cortically lesioned group (β=1.00). In addition, both the control group (d'=2.24) and left cortically lesioned group (d'=1.86) tend to be more successful at discriminating correct from incorrect responses than the right cortically lesioned group (d'=1.61). It should be repeated that these are only trends in the data and do not represent statistically significant differences.

Summary of Recurring Figures Test Results

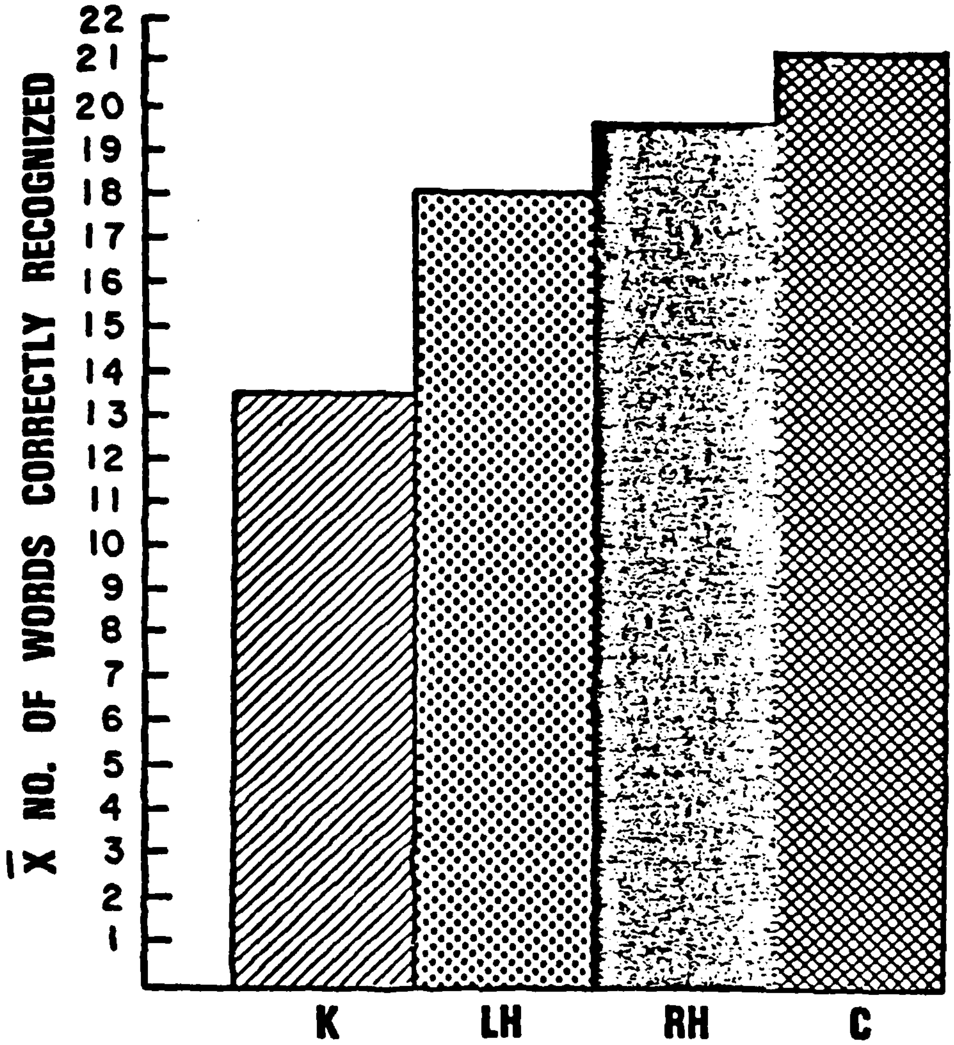
The results reported above reveal several interesting findings. Perhaps the foremost result is that the left cortically lesioned group's inferior verbal memory performance is not extended to recognition memory for designs. In general, there was a non-statistical tendency for the right cortically lesioned group to be more impaired (more false-positive responses and fewer hits) than the left cortically lesioned group, which in turn was more impaired than the control group. This pattern of performance only reached significance for geometric design false-positive recognition errors. The Korsakoff group consistently had the fewest hits and fewest false-positive errors. All groups had a better performance (more hits, fewer false-positive errors) for the geometric design than nonsense design stimuli. The right cortically lesioned group had the least conservative strategy and the most difficulty in discriminating old from new designs. These results weakly confirm the specificity of the left cortically lesioned group's verbal-memory impairment. Comparisons of design recognition performances to the results of a Word Recognition Test will be presented below.

WORD RECOGNITION TEST

A test of word recognition for those words used as stimuli in the Selective Reminding Tests was administered. The purpose of this test was to consider whether a recognition test would be more effective than a recall test in assessing whether a stimulus word was in fact encoded into long term store, whether there remained an effect of word frequency on retrieval, whether a particular group had a tendency to commit a particular type of false-positive error, and finally to assess the sensitivity and criterion levels of each group by a *signal detection analysis*. The results are presented below.

Hits (Words Correctly Recognized)

A one-way ANOVA was computed for the comparison of combined (low frequency + high frequency words) hits between groups. There was a significant effect ($F(2,51)=5.28$, $P<.01$) for the between groups condition (see Figure 20). A post-hoc Tukey Test comparison was significant ($P<.01$) for the control versus left-hemisphere group. No other group comparisons reached significance. In addition, it can be seen (in Figure 20) that the Korsakoff group's performance fell well below that of the other groups. It should also be noted that the control and experimental groups were nearly at ceiling



WORD RECOGNITION TEST – HITS

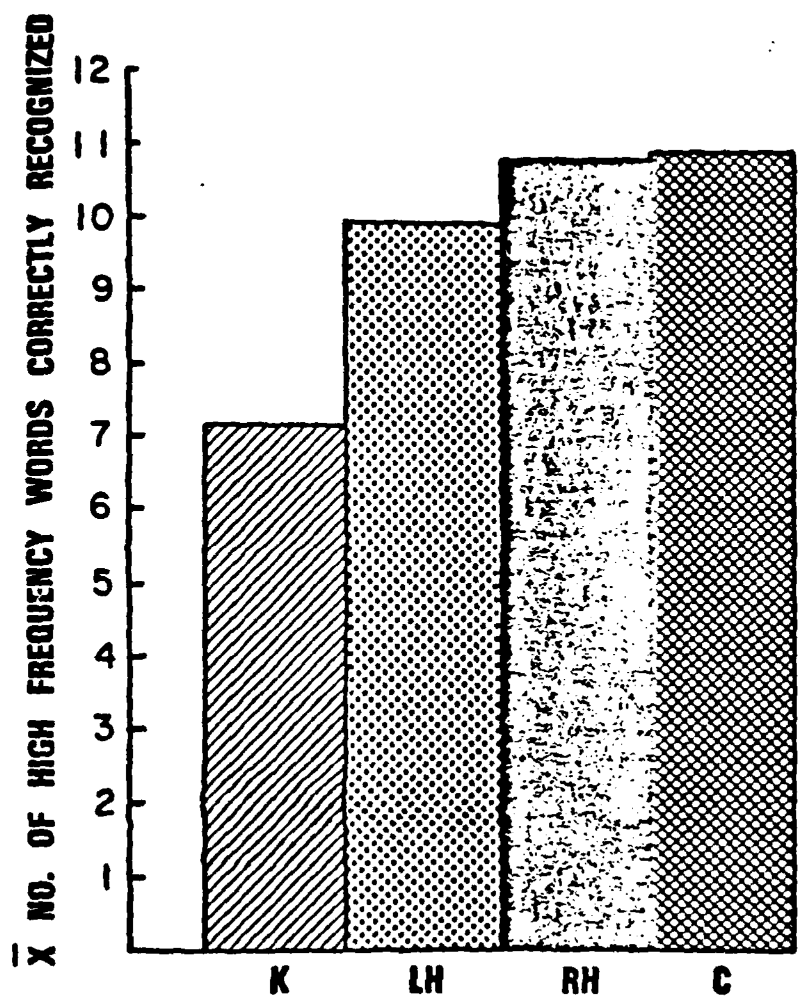
FIGURE 20

levels. Further analyses were performed to assess the effect of word frequency upon later recognition.

Figure 21 illustrates the $\overline{X}$ number of high frequency/imagery words correctly recalled. A one-way ANOVA for the between groups condition did not reach significance ($P<.10$), although the left cortically lesioned group's performance tended to fall below that of the other contrast groups. The Korsakoff group's performance is little better than chance and fell well below that of the other groups.

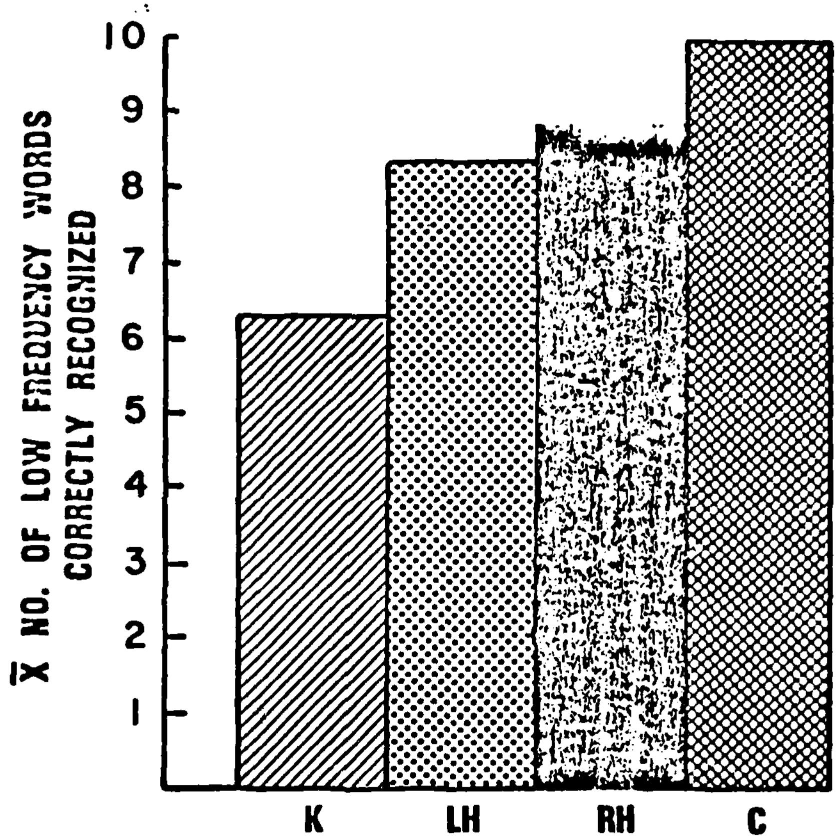
A between group comparison for $\overline{X}$ number of low frequency words correctly recognized (see Figure 22) by one-way ANOVA reached significance ($F(2,51)=3.28$, $P<.05$). Post-hoc analysis by Tukey Tests revealed only one comparison (control vs. left cortically lesioned) to have reached significance ($P<.05$). The Korsakoff group once again had a performance that fell well below that of the other groups. It appears that the control group - left cortically lesioned group difference for low-frequency word recognition is what most contributes to the same group's difference for the combined recognition performance detailed above.

The analysis of correct recognition of words show both the control and right cortically lesioned groups to be performing at near ceiling levels. The left cortically lesioned group's hit rate falls below that of the controls and right cortically lesioned groups, significantly so for the low frequency/imagery words. The Korsakoff group's hit rate is well below that of the comparison groups and hovers around chance.



WORD RECOGNITION TEST – HIGH FREQUENCY WORDS – HITS

FIGURE 21



WORD RECOGNITION TEST — LOW FREQUENCY WORDS — HITS

FIGURE 22

Several points deserve mention. First, whatever recall differences appeared between groups on the Selective Reminding Tests are for the most part eliminated (as far as the hit rate is concerned) on a Word Recognition Test. This change is particularly dramatic for the left cortically lesioned group. Second, even though the Korsakoff group's performance on total recall and long term retrieval measures approached the level of the left cortically lesioned group by the late trials of the Selective Reminding Test, these gains were not reflected in the Korsakoff group's word recognition hit rate which fell well below that of the left-cortically lesioned group. Finally, there appears to be an effect of word frequency, particularly for the left cortically lesioned group, which is denoted by a greater difficulty in retrieving and recognizing low-frequency/imagery words than high frequency/imagery words.

Signal Detection Analysis

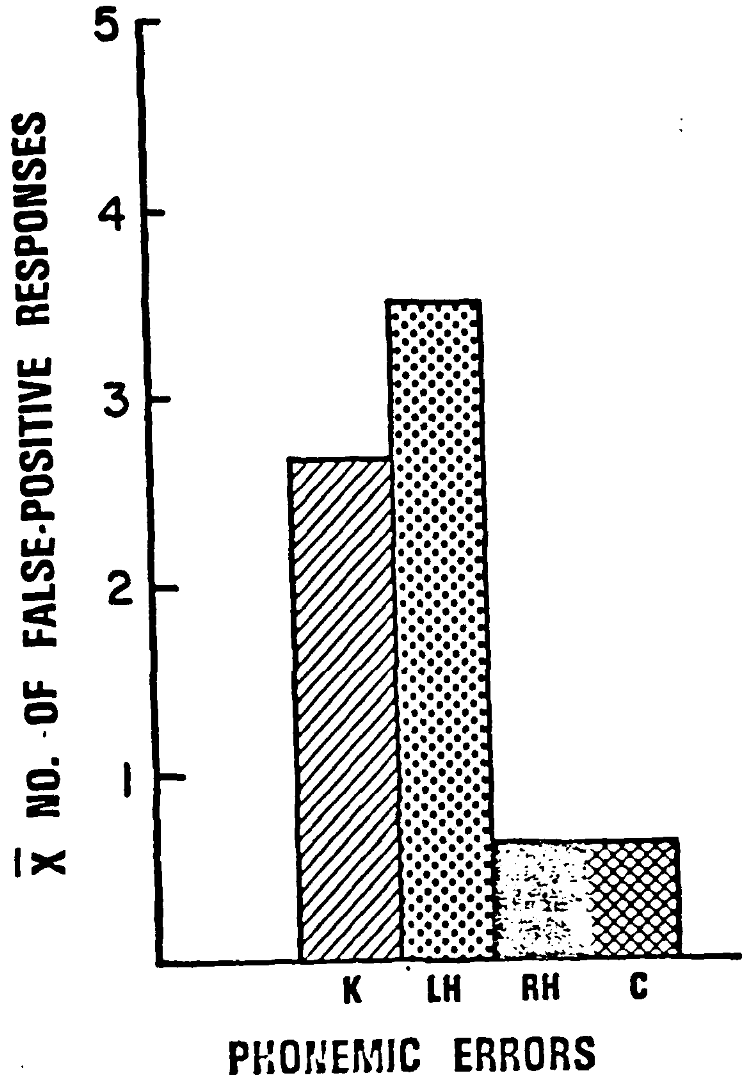
A signal detection analysis was performed to assess the independent effects of sensitivity and decision criterion upon word recognition performance. A perusal of $\overline{X}$ hit (number of words correctly recognized) rates (controls group=21.56, right cortically lesioned group=19.72, left cortically lesioned group=18.33) and mean false-positive error rates (control group=1.5, right cortically lesioned group=2.22, left cortically lesioned group=7.44) suggested that hit rates were similar, but false-positive rates pointed to a specific impairment of the left cortically lesioned group's word recognition process. Below, the specific false-positive error types will be analyzed.

Before proceeding to those analyses, the results of a signal detection analysis will be presented in the hope of shedding light on the reason for the left cortically lesioned group's high false-positive error rate.

d' computation was performed on each member of each group (control group $\bar{X}$ d'=4.10, right cortically lesioned group $\bar{X}$ d'=3.53, left cortically lesioned group $\bar{X}$ d'=2.54). A one-way ANOVA computed following the log transformation of each d' score was significant ($F(2,51)=13.50$, $P<.001$). A post-hoc Tukey Test revealed that the d' rates for both the control and right cortically lesioned groups were significantly ($P<.01$) different from the left cortically lesioned group. No other comparison reached significance. A one-way ANOVA for differences in criterion level (control group $\bar{X}$=1.54; right cortically lesioned group $\bar{X}$ =2.02; left cortically lesioned group $\bar{X}$ =1.90) did not reach significance. These findings suggest that the high false-positive error rate found in the left cortically lesioned group is due to a problem in stimulus discrimination and not a problem in criterion setting. In light of this interpretation the analysis of false-positive error types becomes increasingly important as a clue to the source of the left-hemisphere detection deficit. Those analyses can be found below.

False-Positive Responses

As can be seen in Figure 23, the left cortically lesioned group committed significantly ($F(2,51)=11.46$, $P<.001$) more phonemic false-positive errors than either the right cortically lesioned group



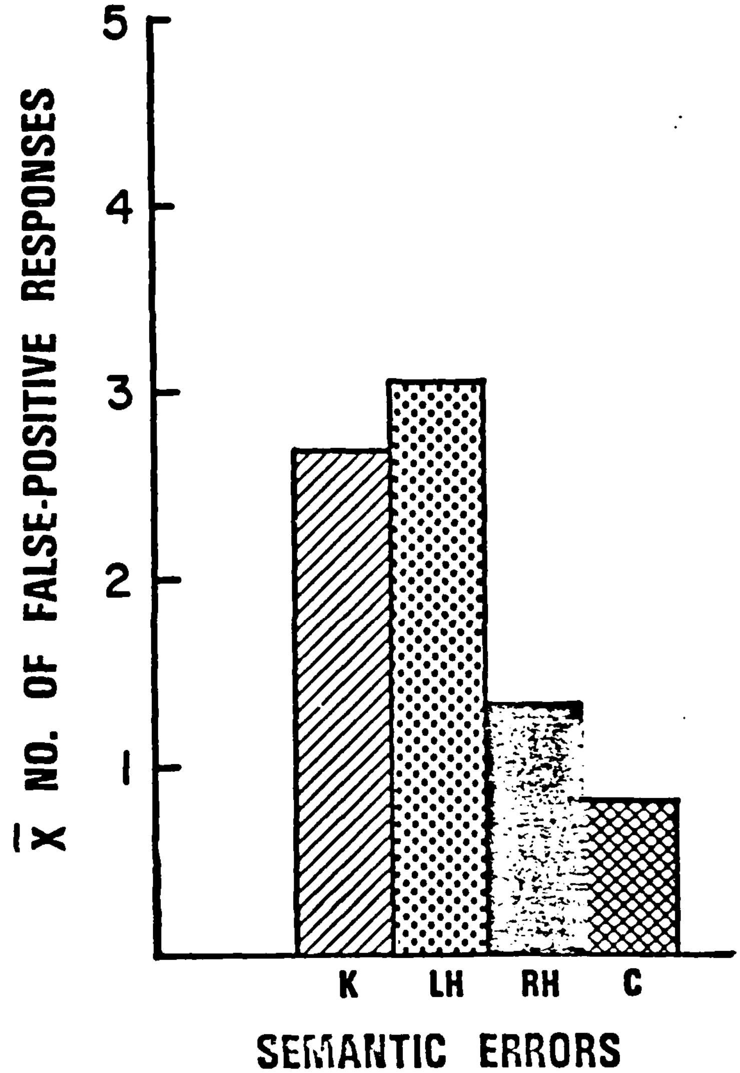
WORD RECOGNITION TEST:
PHONEMIC FALSE-POSITIVE RESPONSES

FIGURE 23

(P<.01) or control group (P<.01). Figure 24 illustrates the semantic false-positive error rates for each group. The left cortically lesioned group committed significantly (F2,51)=4.43, P<.05) more semantic false-positive errors than the control group (P<.05), but a comparison with the right cortically lesioned group did not reach significance. There were no significant differences for the analysis of random false-positive error rates. These foils were chosen to have no apparent relationship (i.e., phonemic or semantic) to the target words (see Figure 25). The Korsakoff group's false-positive error rates approached that of the left cortically lesioned group for both the semantic and phonemic false-positive measures (Figures 23 and 24) and surpassed all groups on the random false-positive measure (Figure 25).

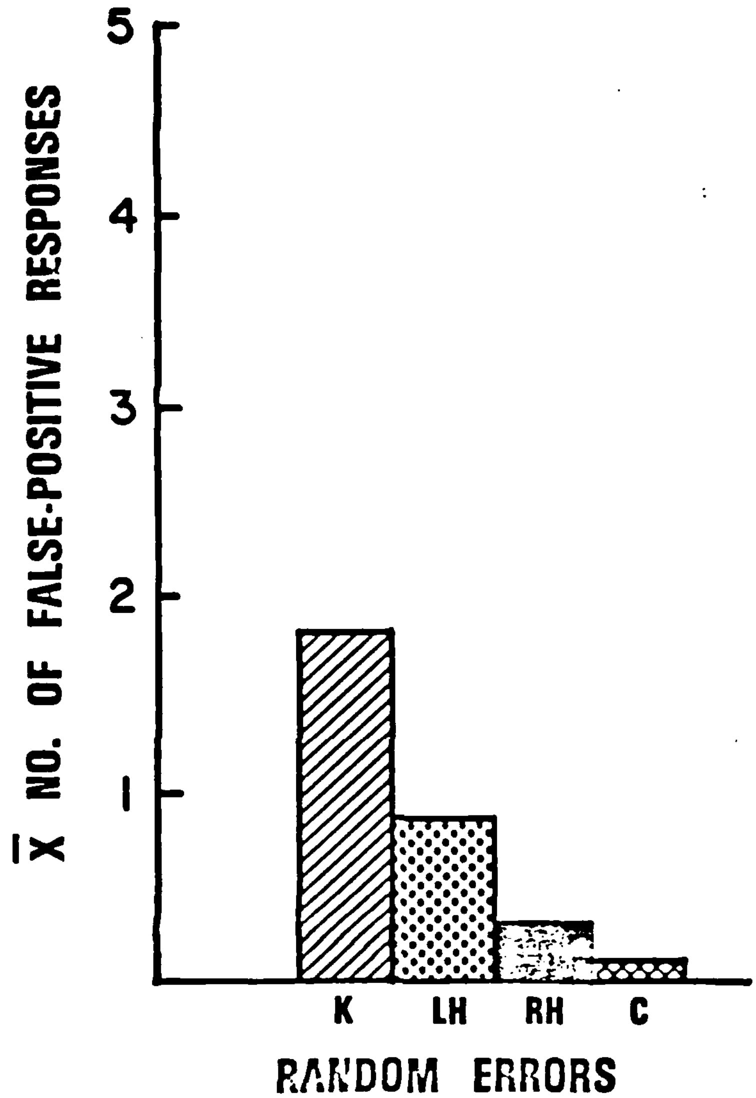
A final analysis was computed across groups for the ratio of phonemic to semantic false-positive errors. A one-way ANOVA was highly significant (F(2,51)=19.10), P<.001). Post-hoc analysis by Tukey Test revealed that the left cortically lesioned group had a significantly higher ratio score than either the right cortically lesioned group (P<.01) or control group (P<.01). Figure 26 shows the left cortically lesioned group's $\overline{X}$ ratio score of 1.07 which can be accounted for by a greater phonemic than semantic false-positive error rate. It can be seen that the inverse error rate relationship holds for all other groups (including the Korsakoff group).

The results of the false-positive error analysis revealed that the left cortically lesioned group had committed more combined false-



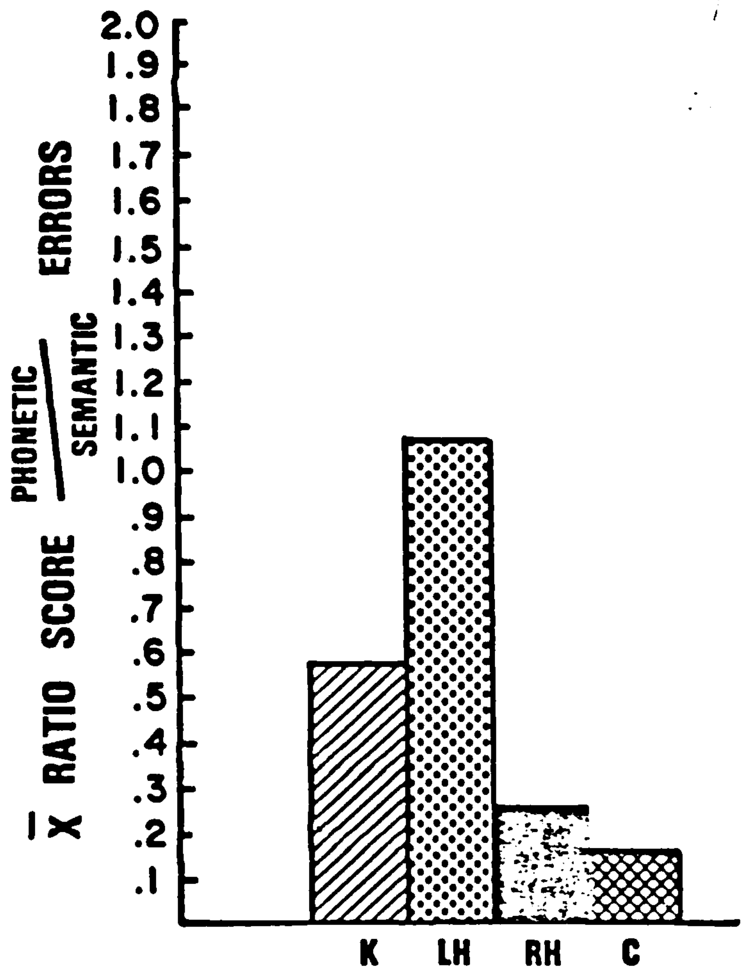
WORD RECOGNITION TEST:
SEMANTIC FALSE-POSITIVE RESPONSES

FIGURE 24



WORD RECOGNITION TEST:
RANDOM FALSE-POSITIVE RESPONSES

FIGURE 25



WORD RECOGNITION TEST RATIO SCORE:
PHONEMIC / SEMANTIC FALSE-POSITIVE RESPONSES

FIGURE 26

positive responses than any other group (particularly phonemic false-positive responses). Although there was no statistical difference among the comparison groups for random false-positive error rates, (see Figure 25) the Korsakoff group tended to commit more than any of the comparison groups. The Korsakoff group committed nearly as many false-positive responses overall as the left cortically lesioned group, while the control group's false-positive error rate was extremely low across error types. The right cortically lesioned group committed more semantic and random false-positive responses than the control group, but these differences did not approach significance. Thus, the outstanding false-positive error rate of the left cortically lesioned group is primarily due to the contribution of phonemic false-positive reponses which may partially explain the left cortically lesioned group's poor performance on the Selective Reminding Test (see comments in Discussion Chapter). Since the Korsakoff group's false-positive error rate was consistently high for all error types, a specific encoding explanation for their verbal learning impairment may be suspect. This interpretation will also be commented upon in the Discussion Chapter. Finally, the right cortically lesioned group's tendency towards greater semantic false-positive error rates when compared to the control group suggests that there may be some impairment of the right-hemisphere's semantic processing mechanisms that contribute to verbal learning and memory.

VII. DISCUSSION

This experiment was designed to test several hypotheses regarding the representation of memory processes in the human brain. A model of memory process representation in the human brain was developed in Chapter III. Briefly, this model postulated that both short term memory mechanisms and long term storage critical for complex verbal communication and reasoning were located in the cortex. The transfer of verbal information from the short term store state to the long term store state was accomplished by a tagging mechanism dependent upon normal hippocampal-limbic system functioning.

To test this model, six specific hypotheses were generated. These hypotheses, utilizing measures of total recall, long term retrieval, long term storage, correct recognition, and false-positive responses were tested in subjects with varying central nervous system location of lesions. The experiment used conventional tests of memory because a population of cortically lesioned, non-aphasic subjects had not previously been utilized in the literature to support or disconfirm contemporary models of memory. Thus, uncertainty existed as to how they would perform on what was essentially a verbal learning and recognition task. A clinically diagnosed Korsakoff patient group was also tested for qualitative comparisons, since Korsakoff patients are known to have lesions primarily distributed in subcortical-limbic regions (e.g., the dorsomedial thalamus and mammillary bodies) of the brain.

Though formal parametric analyses were not computed (when contrasting the Korsakoff group's performance), it was decided that even qualitative comparisons between a sample of subcortically lesioned patients and 2 different samples of cortically lesioned patients could provide useful information. Six hypotheses to be tested were generated from the model (see Chapter III). Below, each hypothesis is listed along with a brief summary of the major findings that pertain to it. Following this section, a description of performance by each patient group is offered with a tentative explanation for the performance. Finally, an attempt is made to place the findings and model in relationship to the recent neuropsychological literature on memory functioning.

HYPOTHESES TESTING

Hypothesis No. 1. Hypothesis #1 suggested that the left cortically lesioned group would be significantly inferior on total recall, retrieval, and storage measures on only the early trials of the Selective Reminding Test when compared to the right cortically lesioned and control groups. The left cortically lesioned group had been expected to dramatically improve their performance over trials since it was hypothesized that the early trial deficits would be due to a linguistic factor that could be overcome by repeated presentation of stimuli. In fact, the left cortically lesioned group performed significantly inferior to the control group on the above mentioned measures on early and later trials. The right cortically lesioned group tended to perform similarly to the left cortically lesioned group on the first few trials of the recall task, but their performance on later trials more closely resembled that of the control group. The right cortically lesioned group more closely conformed to the slope prediction of hypothesis #1, while the left cortically lesioned group did not. Therefore, hypothesis #1 was rejected.

Hypothesis No. 2. Hypothesis #2 stated there would be an interaction between word frequency and groups. A quantitative comparison of performance indicated several interactions. There was a striking serial position effect on trial one of the Selective Reminding Test composed of low frequency/imagery words. The left cortically lesioned group showed a marked depression for $\overline{X}$ total recall for the first few serial positions (usually referred to as the secondary or long term memory component of the serial position recall curve) suggesting an impaired ability to transfer information from short term (the recency portion of the recall curve was unaffected) to long term store. There was a nonsignificiant trend given word frequency characteristics (apparent for $\overline{X}$ consistent long term and (combined) long term retrieval from long term storage) for both the left cortically lesioned group and the Korsakoff group with low frequency/imagery words being more difficult to retrieve from long term storage (than high frequency/imagery words) despite relatively equivalent storage levels across word frequency/imagery type. Thus, hypothesis #2 is only partly supported as there appeared to be no striking word frequency/imagery effect for the right cortically lesioned group while only selected measures suggested the tendency for a word frequency/imagery effect in the left cortically lesioned group.

Hypothesis No. 3. Hypothesis #3 stated that a correlation between fluency and total recall should occur when a similar retrieval mechanism or lexicon is utilized or impaire . Given the model discussed in Chapter III, the left cortically lesioned group would be the most likely candidate to have an impaired lexicon/lexical retrieval process and in turn demonstrate the highest positive correlations computed. This hypothesis was rejected. The right cortically lesioned group showed the most consistent and highest positive correlations. Since the majority of research reviewed suggested that the right cortically lesioned group should be able to utilize an intact left-hemisphere lexicon, an explanation offered for their performance is that their retrieval performance (which was depressed when compared to a control group) was due to an attentional, i.e., resource allocation, deficit.

The left cortically lesioned group did achieve small but significant correlations only between their category and combined fluency production and total recall for the high frequency/imagery words. They failed to achieve significant correlations when performance on either the low frequency/imagery recall measure or the letter fluency task was compared. Both these variables place a heavier burden upon acoustic/phonemic processes. A plausible explanation for the left cortically lesioned patient's inconsistent performance on these variables would be that they have impaired phonemic processing mechanisms. In addition, the generally low, albeit significant correlations that were achieved indicate that probably more than one explanation (e.g., impaired phonemic processing and a lexical storage or attentional deficit) is necessary to describe the left cortically lesioned group's inferior performance on both free recall and word fluency tasks.

The control group's performance was highly correlated only when combined and category fluency measures were correlated with recall of low frequency/imagery words. This can be explained by a similar difficulty level for these tasks, whereas the control group achieved a near ceiling-level performance for free-recall of high frequency/imagery words and performed more variably (in terms of total fluency output) on a letter fluency task. This would account for the low correlations achieved when these tasks were correlated.

Hypothesis No. 4. Hypothesis #4, which stated that the left cortically damaged group would have a significantly lower $\overline{X}$ d' score than either the right cortically lesioned or control groups on a Word Recognition Test, was strongly supported. This finding demonstrated that the left cortically lesioned group had a distinct deficit in stimulus discrimination (perhaps phonemic discrimination) on a task requiring recognition of verbal items. Since all subjects were able to correctly identify all words used, the stimulus discrimination deficit is considered part of a memory process rather than a reading deficit.

Hypothesis No. 5. Hypothesis #5, which stated that the predominant false-positive error type on the Word Recognition Test would be phonemic for the left cortically lesioned patient and semantic for the right cortically lesioned patient, was strongly supported. This finding emphasized that a phonemic processing impairment was a significant factor in the left cortically lesioned group's attempt to retrieve verbal information from long term store as represented by their performance on a Word Recognition Test.

Although the right cortically lesioned group committed more semantic than phonemic false-positive responses on the Word Recognition Test, their false-positive response totals for all categories (i.e., semantic, phonemic, or random) did not differ significantly from that of the control group.

Hypothesis No. 6. Hypothesis #6 stated that the right cortically lesioned group would have a significantly inferior d' score compared to that of the left cortically lesioned and control groups on the Kimura Recurring Figures Test. This hypothesis was not supported as no significant differences emerged from parametric comparisons. Nevertheless, a nonsignificant trend in the direction of the prediction was observed. This finding weakly supports the inference that the verbal learning and memory deficit seen in the left cortically lesioned group is not representative of a generalized cognitive impairment that would always find that particular lesion group to have an inferior performance when compared to other pathological contrast groups or a control group.

One possible explanation for the lack of a statistically significant finding on this task is that the cortical lesion groups did not have hippocampal damage. Previous studies that have utilized this task to explore differences in memory processing between the cerebral hemispheres included hippocampal damaged subjects. Those studies showed the right hippocampal lesioned patients to have an outstanding visual-spatial memory deficit (Kimura, 1963; Milner, 1967). The weaker finding (of a trend) seen in this study may be due to visual-spatial perceptual deficits (the right hemisphere is thought to be dominant for visual-spatial perception, particularly in the case of nonverbalizable stimulus presentation) that are observed more frequently following right hemisphere lesions. Given a temporal-parietal locus of lesion rather than medial temporal (which would include the hippocampus), it is more probable that a poor performance on the Recurring Figures Test would be more attributable to a visual spatial than memory deficit.

The Korsakoff group presents with subcortal-limbic lesions that have been functionally compared to hippocampal lesions because of their similar effect on memory processes (Butters and Cermak, 1980). On this task, the Korsakoff group had a lower hit rate and lower false-positive response rate than all other groups. This paradoxical performance is a probable result of both poor discrimination and a conservative criterion level. Their overall performance was more similar to the right temporal lobectomy patients reported in the Kimura (1963) and Milner (1967) studies than to the cortically lesioned groups used in the present study.

The factors described above suggest that the Kimura Recurring Figures Test may not have provided the strongest test for hypothesis #6 despite a trend in group performance in the predicted direction.

An additional factor to support this contention involves the concept of a lexicon. It is clear that the stimuli used for the Word Recognition Test were available in the lexicon of all subjects (even the low frequency/imagery words were read with little trouble). It is not clear that a right-hemisphere lexical counterpart existed for the nonsense and geometric designs used in the Kimura Recurring Figures Test. In the case of the nonsense designs, it is highly unlikely. This difference in tasks reduces the strength of the test of its hypothesis. Given the cognitive process differences of each hemisphere, the lesion location, and the stimuli contained in the Kimura Recurring Figures Test, an absolute test of differential deficit has not been utilized in this study. Nevertheless, the fact that the left cortically lesioned group tended to outperform the right cortically lesioned group on this task may still be considered as (suggestive) support for the differential deficit postulated in hypothesis #6.

The results of this study have implications for the model of memory processing presented in Chapter III and for future research directions. Before proceeding to discuss the results in light of the model, a brief characterization of each experimental group's performance is warranted.

Characterization of the Left Cortically Lesioned Group's Deficit.

The group with cortical lesions in the distribution of the left middle cerebral artery presented with an interesting and explain-able impairment in verbal learning and memory. For the most part, the cerebral vascular accidents suffered by these patients appeared small in scope (based on CT scan summary reports), resulted in only a temporary (or mild) residual right hemiparesis and/or visual field cut. The location for most strokes was the posterior frontal and parietal-temporal regions of the left cerebral hemisphere. As previously mentioned, some subcortical damage (i.e., white matter tracts, basal ganglia) probably occurred, but radiological evidence (e.g., CT scan) failed to demonstrate the presence of midline (thalamus or mammillary bodies) or medial temporal (hippocampi) damage. Thus, the lesions appeared restricted to cortical areas generally associated with linguistic processes (see model), despite the fact that subjects with clinically obvious language deficits were excluded, so that the patients who were evaluated would provide an adequate test of the hypothesis without the confound of a serious language disorder. Both comprehension and expression of normal conversation appeared within normal limits. Given this background, the characterization of the left cortically lesioned group's deficit should not be subject to serious dispute.

The left cortically lesioned patient group demonstrated a striking impairment on a verbal learning task (Selective Reminding Test). They were unable to approach either the control or right cortically injured group in terms of total recall, long term storage, or long term retrieval. This was particularly striking for the late trials (7-10) on the task. Despite demonstrating some learning over trials, the left cortically lesioned group's performance was only slightly superior to the Korsakoff group's performance by the later trials. Given that no language deficits were strikingly obvious in these patients, it is clear that they present with verbal learning and memory problems which are somewhat exaggerated by the use of low frequency/imagery words as stimuli.

The poorer performance of the left cortically lesioned group on the verbal learning task extended to the Word Fluency Test, although here the contrast to the right cortically lesioned group was not as striking. Although the left cortically lesioned group appears impaired on this task, the impairment can be thought of as a general slowing of lexical search (which is also seen in the right cortically lesioned group) that is at least partially independent of the verbal learning and memory problems evidenced on the Selective Reminding Tests.

The Recurring Figures Test proved easier for the left cortically lesioned group as demonstrated by their overall performance advantage over the right cortically lesioned group. This finding supports the characterization of the left cortically lesioned group's deficit as being predominantly verbal/linguistic, i.e., a relatively specific as opposed to general impairment of cognitive functioning.

The left cortically lesioned group's long term (and consistent) retrieval deficits seen on the Selective Reminding Test were not as apparent on the Word Recognition Test. While their correct recognition performance was inferior to that of the control and right cortically lesioned groups, it was much better than chance and significantly better than might be expected on the basis of their Selective Reminding Test performance alone. This finding suggests that clinicians should be cautious when noting that a patient is unable to encode (on the Selective Reminding Test) many words into long term storage on a free recall test since that measure may not entirely reflect long term storage processes, but may only reflect a specific subset of the long term storage process.

Despite a relatively good recognition (or "hit") score on the Word Recognition Test, an analysis of false-positive responses showed the left-cortically lesioned group to have committed significantly more phonemic false-positive responses than any other group, and to have committed more phonemic than semantic false-positive responses. While they also committed more semantic false-positive responses than the right cortically lesioned group, this difference did not reach significance (as was true of the comparison of random false-positive responses).

This pattern of false-positive responses suggests that the left cortically lesioned group is particularly susceptible to acoustic/phonemic errors, even when a long term retrieval process is required. This conclusion supports the hypothesis that at least part of the verbal learning and memory deficit of this group is due to impairment of phonemic processing mechanisms. Since their letter fluency task performance was not strikingly different from their category fluency task performance (relative to the other groups), the impaired (phonemic processing) performance of the left cortically lesioned group on verbal learning tasks cannot be attributed primarily to a generative or simple retrieval deficit. It does appear clear that this type of lesion results in a phonemic processing deficit (independent of a clinical language impairment) that affects the ability of patients to retrieve words from long term or episodic memory (but not semantic memory since this deficit did not account for an asymmetric performance on the Word Fluency Test.)

It was also seen on the Selective Reminding Test that the left cortically lesioned patients were able to encode more words into long term storage than they were generally able to retrieve (especially in a consistent fashion). This finding suggests that in addition to a phonemic processing deficit, the left cortically lesioned group also had a retrieval process deficit. The combination of impaired phonemic processing (also see signal detection analysis for the Word Recognition Test) and long term retrieval, and the general effects of brain injury (slowed cognitive processes) may account for the performance of left cortically lesioned patients on verbal learning tests, while providing some support for the model of memory presented in Chapter III.

Characterization of the Korsakoff Group Performance

In general, the Korsakoff group demonstrated the most cognitive impairment across tasks. On the Selective Reminding task, their long term retrieval and long term storage abilities did approach the left cortically lesioned patients by the later trials of the task. However, this apparent learning ability did not transfer to the Word Recognition Test where their correct recognition performance fell well below that of the other groups, whereas their $\bar{X}$ number of false-positive semantic and phonemic responses was similar to the left cortically lesioned patients (while committing many more random false-positive responses).

The high number of random false-positive responses suggests that the Korsakoff group's ability to apply semantic or even phonemic constraints to verbal stimuli in order to distinguish them from other verbal stimuli is impaired. This pattern of results was similar on the Kimura Recurring Figures task except that the Korsakoff group not only had the fewest hits, but the fewest false-positive errors as well, suggesting that they employed a more cautious criterion level on this task. Their overall fluency level fell between that of the right cortically lesioned and left cortically lesioned groups.

The Korsakoff group's overall performance suggests that they have a profound memory disorder which is characterized by a more cautious performance on nonverbal than verbal testing. They are capable of exhibiting some learning on a verbal learning task (in fact approaching the left cortically lesioned group in total recall), but this learning momentum is not maintained when verbal memory was evaluated by a delayed Word Recognition Test. Their fluency ability was similar to the right cortically lesioned group on both letter and category fluency tasks, although they did not benefit as much as the left or right cortically lesioned group from category as contrasted with letter fluency stimuli. They clearly have difficulty in applying semantic/categorical constraints to verbal or nonverbal stimuli. It is not clear whether this is primarily an encoding or retrieval problem, although the Korsakoff group fluency is comparable to the right cortically lesioned group (*suggesting* retrieval from semantic memory is relatively intact when contrasted with retrieval from episodic memory on the Selective Reminding, Word Recognition, and Kimura Recurring Figures Tests). Since they eventually learned at a rate similar to the left cortically lesioned group on a free recall task (although their word and figure recognition was especially poor), the evidence indicates that the specific processes involved in the Korsakoff patient memory deficit includes not only retrieval (or storage) mechanisms but also the application of the word/figure characteristic constraints that make a word or figure distinctive.

Characteristics of the Right Cortically Lesioned Group.

The right cortically lesioned group's performance on verbal learning and memory tests can best be characterized by the phrase "slow but steady." That is, on the Selective Reminding Tests, this group's performance on early trials on measures of total recall, long term storage, and long term retrieval resembles that of the left-cortically lesioned group. However, by the late trials, the right cortically lesioned group's performance more closely resembles that of the control group. This control group-right cortically-lesioned group similarity in performance was maintained on the Word Recognition Test. Despite a performance similarity to the control group, the right cortically lesioned group's performance was generally inferior (but not significantly so) to the control group. This was particularly noticeable for the semantic false-positive response measure on the Word Recognition Test.

The performance of the right cortically lesioned group on the word fluency task tended to fall between that of the control and left cortically lesioned groups. This positioned relationship of groups is similar to that seen on the Selective Reminding Tests. Correlational studies computed between first trial free recall on the Selective Reminding Tests and fluency measures showed the right cortically lesioned group's performances to be highly correlated which suggested that a unitary explanation could account for a significant proportion of the variance in performance on both these tasks.

A simple explanation that might account for both performance decrements is an impairment in resource allocation. Well known clinical phenomena associated with right-hemispheric lesions include impersistance, neglect, inattention, and difficulty in initiation of an action. These descriptions of deficit can be reduced to a common impairment, i.e., the inability to allocate effort in processing environmentally produced stimulus information or in generating stimulus seeking information. This resource allocation impairment has a tendency to be reduced with practice on a task, although hemispatial inattention may persist. This explanation is compatible with the findings on the verbal tests administered in this experiment with the exception of the semantic false-positive error rate on the Word Recognition Test where the right cortically-lesioned group's error rate more closely approximates that of the left-cortically lesioned group.

Zaidel (1978) has described a limited right-hemisphere lexical organization that could be specialized for imaginal/visual attributes and/or processing mediators which assist in encoding attributes of a word. Thus, lesions in the right hemisphere could impair the capabilities for lexical encoding and storage so that semantic false-positive responses would become more likely (given the impairment of a component of verbal semantic encoding mechanisms-imagery) on a Word Recognition Test. A prediction that also follows, although not tested, is that a significant number of semantic intrusions should occur on free recall tests. Since aging subjects, depressives, and electronconvulsive therapy patients, as well as normals tend to commit semantic rather than acoustic/phonemic or random false-positive responses (Whitty and Zangwill, 1977), this semantic-imaginal explanation deserves further research.

A final observation is that the right cortically lesioned group tended to have the poorest performance on most measures of the Recurring Figures Test. Since they performed better on the verbal tasks relative to the left cortically lesioned group, their inferior performance on this task appears specific and probably reflects impaired visual-spatial processing as would be expected from a right hemisphere lesion. The right cortically lesioned group's performance was not significantly different from the other groups (with the single exception of the geometric design false-positives measure) probably because of the lack of midline temporal lobe and/or hippocampal structural compromise. Since the recurring figures task is considered a memory test, the absence of such a lesion would require the burden of explanation for the deficit to be placed on visual-spatial perceptual deficits. By definition the Kimura Recurring Figures Test is predominantly a visual-spatial memory task, so that a visual-spatial perceptual deficit explanation might account for the smaller than expected differences between right and left cortically lesioned groups. Previous research has shown that if patients with known hippocampal lesions are included in the contrast groups, the right hippocampal lesioned group's recognition and false-positive scores tend to be significantly inferior to those that of the left hippocampal lesioned group, particularly for the nonsense designs (Milner, 1967).

The inclusion of the right cortically lesioned group as an age and education matched contrast group has allowed the left-cortically lesioned group's verbal learning and memory deficits to be more clearly delineated.

A Reevaluation of the Model

The results of this experiment can be discussed in terms of the model presented in Chapter III. The finding that the left cortically lesioned patients have a striking phonemic processing deficit is in keeping with the role of the left cerebral cortex in articulatory rehearsal and phonemic discrimination as postulated in the model. The identification of a long term <u>memory process</u> impairment in the left cortically lesioned group as exemplified by their retrieval performance on a verbal free-recall learning task, was not accounted for by the model. The model defined the memory impairment of the left-cortically lesioned group as being either short term (due to a phonemic deficit) or long term (impaired consolidation of information in lexical or semantic storage). The performance of the left cortically lesioned group on the Selective Reminding Test suggested an intact verbal span, but impaired long term storage, and in particular, inconsistent retrieval from long term storage. Either the thresholds of these newly encoded words are non-distinct, retrieval mechanisms are impaired, or the ability to use elaborative strategies to insure a deeper level of encoding is impaired (or all three). Further research must elucidate the answer.

The improved performance of the left cortically lesioned patients on the Word Recognition Test (despite the noted false-positive response pattern) compared to the Selective Reminding Tests does suggest that verbal stimuli may be contextually coded to some degree, but the contextual or distinctive boundaries are degraded by impaired phonemic and to a lesser extent semantic coding; both processes are cortically located as defined by the model.

The Korsakoff patient's performance demonstrates minimal verbal learning skills for new information and offers little evidence that verbal or nonverbal contextual tagging takes place. This conclusion is supported by the large number of random errors committed on the Word Recognition Test, the few words encoded into long term storage on the selective reminding task (although these few words in long term storage were better utilized than the greater number that reached long term storage in the left cortically lesioned group), and the lack of obvious improvement in verbal memory on a recognition as compared to recall task. In addition, there is little evidence of a serial position effect (for first trial recall) on free recall tests for the Korsakoff group. All these factors support the impairment of subcortically based memory processes.

The fact that the Korsakoff patients seem to be able to utilize those words that reach long term storage suggests that recall of those words may not be compromised by an increased probability of semantic or phonemic intrusions or false-positive responses, a deficit that should be seen only with cortical involvement. However, if a word does not reach long term storage, semantic, phonemic and random intrusions or false-positive responses may occur in the subcortically lesioned patients. These findings expand the model's description of subcortical versus cortical lesion effects upon verbal memory.

The right cortically lesioned group's performance on verbal memory tests is depressed due to impaired resource allocation and a semantic lexical process (imagery) component dysfunction. This explanation of the right cortically lesioned group's depressed verbal learning performance is compatible with the model, although the effects of resource allocation were not taken into account and the contribution of the right hemisphere's lexical processes had been considered minimal. While they may be minimal, their impairment nevertheless reduces the efficiency of verbal memory processing (particularly semantic processing) in the right cortically lesioned group.

The model, generally supported in this study, is only a rudimentary structure. It is comparable, in the basic processes it attributes to cortical and subcortical structures, to Wickelgren's recent theory of learning and amnesia (1979), although the model here has not attempted to specify what kinds of cortical or subcortical neurons are involved, nor does the model elaborate on a specific process such as the lexicon.

Future research in this area must involve the use of various rehearsal/mnemonic techniques to control for encoding strategies and to record the type of intrusions on free recall tasks. In addition, word characteristics such as frequency, imagery, and number of meanings need to be manipulated since they have a profound effect on verbal recall and recognition (Jaztrembski, 1981). Given the basic paradigm utilized in this experiment, the experimental manipulations just described above should yield additional valuable information to either support or refute various aspects of the memory model described in Chapter III and elaborated upon above.

In conclusion, the findings of this study suggest that left cortically lesioned patients demonstrate a limited verbal memory deficit that is due both to linguistic (phonemic processing) and to nonlinguistic (retrieval and consolidation) factors. Their performance is both qualitatively and quantitatively superior to Korsakoff patients who demonstrate severely impaired encoding and retrieval processes as a probable result of minimal contextual or episodic tagging of verbal information. Right cortically lesioned patients have a slightly depressed verbal memory, primarily due to a nonmemorial factor (resource allocation), although a minimal semantic-imaginal processing deficit is also hypothesized as being involved in their depressed memory performances. These findings generally support the (simple) model of verbal memory developed in Chapter III. Fut re research is necessary to refine and elaborate the various components of the model.

APPENDIX I

Scoring Protocol for Selective Reminding Test

Summed Recall = total number of words recalled per trial.

Long-Term Retrieval (LTR) = total number of words that were also recalled on the preceding or subsequent trial (at least 2 consecutive trials without reminding).

Long-Term Storage (LTS) = total number of words that have been recalled twice consecutively (minimum) previous to, or subsequent to, (but must include that particular trial in subsequent cases) a trial.

List-Learning (Consistent LTR) = total number of words previous to, including, and immediately subsequent to, a particular trial that are recalled consistently through the end of the task without any further presentation.

BIBLIOGRAPHY

Albert, M. L. (1976) Short term memory and aphasia. Brain and Language 3, 28-33.

Anderson, J. R. (1976) Language, Memory and Thought. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Anderson, J. R. (1978) Arguments concerning representations for mental imagery. Psychological Review 85, 249-277.

Anderson, R. C., and Ortney, A. (1975) On putting apples into bottles- A problem of polysemy. Cognitive Psychology 7, 167-180.

Atkinson, J. R., and Shiffrin, R. M. (1968) Human Memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.), Advances in the Psychology of Learning and Motivation: Research and Theory. Vol. 2, New York: Academic Press.

Baddeley, A. D. (1975) Theories of amnesia. In Kennedy, A. and Wilkes, A. (Eds.), Studies in Long Term Memory. London: Wiley, 327-343.

Baddeley, A. D., and Hitch, G. (1974) Working memory. In G. Bower (Ed.), Recent Advances in Learning and Motivation. Vol. 8. New York: Academic Press.

Barbizet, J. (1970) Human Memory and It's Pathology. San Francisco: Freeman.

Benson, D. F. (1980) Aphasia, Alexia, and Agraphia. New York: Churchill Livingstone.

Blumstein, S. E., Baker, E., and Goodglass, H. (1977) Phonological factors in auditory comprehension in aphasia. Neuropsychologia 15, 19-30.

Boller, F., Kim, Y., and Mack, J. L. (1977) Auditory comprehension in aphasia. In Whitaker, H. and Whitaker, H. A. (Eds.) Studies in Neurolinguistics, Vol. 3, New York: Academic Press.

Borkowski, J. G., Burton, A. L., and Spreen, O. (1967) Word fluency and brain damage. Neuropsychologia 5, 135-140.

Barbizet, J. (1970) Human Memory and Its Pathology. San Francisco: W. H. Freeman and Company.

Bransford, J. D., Franks, J. J., Morris, C. D., and Stein, B. S. (1979) Some general constraints on learning and memory research. In Cermak, L. S., and Craik, F. I. M. (Eds.), Levels of Processing in Human Memory. Hillsdale: Lawrence Erlbaum Associates.

Broadbent, D. E. (1967) Word-frequency effect and response bias. Psychological Review 74, 1-15.

Buschke, H. (1974) Spontaneous remembering after recall failure. Science, 184, 579-581.

Buschke, H. (1975) Retrieval in the development of learning. In Deutsch, J. A. and Deutsch, D. (Eds.), Short Term Memory. New York: Academic Press.

Buschke, H. (1977) Two-dimensional recall: Immediate identification of clusters in episodic and semantic memory. Journal of Verbal Learning and Verbal Behavior 16, 201-215.

Butters, N. and Cermak, L. S. (1980) Alcoholic Korsakoff's Syndrome: An Information Processing Approach to Amensia. New York: Academic Press.

Butters, Samuels, Goodglass, and Brody. (1970) Short term visual and auditory memory disorders after parietal and frontal lobe damage. Cortex, 6, 440-459.

Cermak, L. S. (1975) Imagery as an aid to retrieval for Korsakoff patients. Cortex 11, 163-169.

Cermak, L. S. (1979) Amnesic patients' level of processing. In Cermak, L. S., and Craik, F. I. M. (Eds), Levels of Processing in Human Memory. Hillsdale: Lawrence Erlbaum Associates.

Cermak, L. S., and Moreines, J. (1976) Verbal retention deficits in aphasic and amnesic patients. Brain and Language 3, 16-27.

Chapman, L. J., and Chapman, J. (1973) Problems in the Measurement of Cognitive Deficit. Psychological Bulletin 79, 380-385.

Chapman, L. J., and Chapman, J. (1978) The measurement of differential deficit. Journal of Psychiatric Research, 14, 303-311.

Chapman, R. M., Bragdon, H. R., Chapman, J. A., and McCrary, J. W. (1977) Semantic meaning of words and average evoked potentials. In Desmedt, J. (Ed.), Language and Hemispheric Specialization in Man: Cerebral Event Related Potentials. Basel: S. Karger.

Conrad, R. (1964) Acoustic confusions in immediate memory. British Journal of Psychology 55, 75-84.

Craik, F. I. M. (1970) The fate of primary items in free recall. Journal of Verbal Learning and Verbal Behavior 9, 143-148.

Craik, F. I. M., and Lockhart, R. S. (1972) Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior 11, 671-684.

Collins, A. M., and Quillian, M. R. (1969) Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior 8, 240-247.

Collins, A. M., and Quillian, M. R. (1971) Categories and subcategories in semantic memory. Paper presented at The Psychonomic Society, St. Louis.

Crowder, R. G. (1976) Principles of Learning and Memory. Hillsdale: Lawrence Erlbaum Assocites.

Damasio, A. (1979) The Frontal Lobes. In Heilman, K., and Valenstein, E. (Eds.) Clinical Neuropsychology. New York: Oxford University Press. 360-412.

DeRenzi, E. (1967) Nonverbal memory and hemispheric side of lesion. Neuropsychologia 6, 181-189.

DeRenzi, E., Faglioni, P., and Previdi (1978) Increased susceptibility of aphasics to a distractor task in the recall of verbal commands. Brain and Language 6, 14-21.

Efron, R. (1963) Temporal perception, aphasia, and deja vu. Brain 86, 403-424.

Egan, J. P. (1958) Recognition Memory and The Operating Characteristic. Indiana University: Hearing and Communication Laboratory Technical Report, No. AFCRC-TR-57-50.

Foss, D. J., and Blank, M. A. (1980) Identifying the speech codes. Cognitive Psychology, 12, 1-31.

Frederickson, J. R. (1971) Statistical decision model for auditory word recognition. Psychological Review 78, 409-419.

Fuld, P. A. (1976) Storage, retention and retrieval in Korakoff's syndrome. Neuropsychologia 11, 225-236.

Fuld, P. A., and Buschke, A. (1976) Stages of retrieval in verbal learning. Journal of Verbal Learning and Verbal Behavior 15, 401-410.

Galin, D., and Ellis, R. R. (1977) Indices of Lateralized Cognitive Processes: Relation of Evoked Potential Assymetry to EEG Alpha Assymetry. In Desmedt, J. E. (Ed.) Language and Hemispheric Specialization in Man: Cerebral Event Related Potentials. Basel: S. Karger.

Gardner, H., and Winner, E. (1978) A study of repetition in aphasic patients. Brain and Language 6, 168-179.

Gazzaniga, M. S. (1970) The Bisected Brain. New York: Appleton-Century Crofts.

Geschwind, N. (1965) Disconnection syndromes in animals and man. Brain, 88, 237-294; 585-644.

Geschwind, N., Quadfasel, F. A., and Segarra, J. (1968) Isolation of the speech area. Neuropsychologia, 6, 327-340.

Glanzer, M., and Cunitz, A. R. (1966) Two storage mechanisms in free recall. Journal of Verbal Learning and Verbal Behavior 5, 351-360.

Glass, A. L., and Holyoak, K. J. (1975) Alternative conceptions of semantic memory. Cognition 3, 313-339.

Goodglass, H. (1980) Disorders of naming following brain injury. American Scientist 68, 647-655.

Hecaen, H., and Albert, M. L. (1978) Human Neuropsychology. New York: John Wiley and Sons.

Hintzman, D. L. (1965) Classification and aural coding in short-term memory. Psychonomic Science 3, 161-162.

Hintzman, D. L. (1967) Articulatory coding in short term memory. Journal of Verbal Learning and Verbal Behavior 6, 312-316.

Howes, D. (1978) The Naming Act and Its Disruption in Aphasia. In Aaronson, D. and Rieber, R. W. (Eds.). Psycholinguistic Research: Implications and Applications. Hillsdale: Lawrence Erlbaum. 435-469.

Huppert, F. A., and Piercy, M. (1978) Dissociation between learning and remembering in organic amnesia. Nature 275, 317-318.

Jastrzembski, J. E. (1981) Multiple Meanings, Numbers of Related Meanings, frequency of occurrence, and the lexicon. Cognitive Psychology 13, 278-305.

Joynt, R., and Goldstein, M. N. (1975) The Minor Cerebral Hemisphere. In: Advances in Neurology, Friedlander, W. J. (Ed.). Vol. 7. New York: Raven Press. 147-183.

Kimura, D. (1963) Right-temporal lobe damage. Archives of Neurology 8, 264-271.

Kucera, H., and Francis, W. N. Computational analysis of present day American English. Brown University Press, Providence, R.I. 1967.

Lakoff, G. (1973) Fuzzy grammar and the competence/performance terminology game. Chicago Linguistic Society: 9. Press.

Lesser, R. (1978) Linguistic Investigations of Aphasia. London: Edward Arnold.

Locke, J. L., and Deck, J. W. (1978) Retrieval failure, rehearsal deficiency, and short-term memory loss in the aphasic adult. Brain and Language 5, 227-235.

Luria, A. R. (1966) Higher Cortical Functions in Man. New York: Basic Books.

Luria, A. R. (1976) The Neuropsychology of Memory. Washington, D. C.: V. H. Winston and Sons.

Mandler, G., Pearlstone, Z., and Koopmans, H. J. (1969) Effects of organization and semantic similarity on recall and recognition. Journal of Verbal Learning and Verbal Behavior 8, 410-423.

Marsh, J. T., and Brown, W. S. (1977) Evoked Potential Correlates of Meaning in the Perception of Language. In Desmedt, J. E. (Ed.) Language and Hemispheric Specialization in Man: Cerebral Event Related Potentials. Basel: S. Karger.

Marshall, J. C. (1976) Neuropsychological Aspects of Orthographic Representation. In Wales, R. J., and Walker, E. (Eds.), New Approaches to Language Mechanisms. Amsterdam: North Holland.

Marslen-Wilson, W. D., and Welch, A. (1978) Processing interactions and lexical access during word recognition in continuous speech. Cognitive Psychology 10, 29-63.

Massaro, D. W. (Ed.) Understanding Language: An Information-Processing Analysis of Speech Perception, Reading, and Psycholinguistics. New York: Academic Press.

Massaro, D. W., Taylor, G. A., Venezky, R. L., Jastrzembski, J. E., and Lucas, P. A. (1980) Letter and Word Perception: The Role of Orthographic Structure and Visual Processing in Reading. Amsterdam: North Holland.

McNicol, D. (1972) A Primer of Signal Detection Theory. Sydney: George Allen and Unwin Ltd.

Miller, G. A. (1956) The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological Review 63, 81-97.

Milner, B. (1958) Psychological defects produced by temporal lobe excision. Association for Research in Nervous and Mental Disease, Research Publications 36, 244-257.

Milner, B. (1967) Brain Mechanisms Suggested by Studies of the Temporal Lobes. In Darley, F. L. (Ed.), Brain Mechanisms Underlying Speech and Language. New York: Grune and Stratton. 122-145.

Milner, B. (1974) Hemispheric Specialization: Scopes and Limits. In The Neuroscience: Third Study Program. Cambridge: MIT Press.

Morton, J. (1964) The effects of context on the visual duration threshold for words. British Journal of Psychology 55, 165-180.

Morton, J. (1969a) The interaction of information in word recognition. Psychological Review 76, 165-178.

Morton, J. (1969b) Categories of interference: verbal mediation and conflict in card sorting. British Journal of Psychology 60, 329-346.

Morton, J. (1970) A functional model for memory. In Norman, D. A. (Ed.), Models for Human Memory. New York: Academic Press.

Morton, J. (1979a) Word Recognition. In Morton, J. and Marshall, J. C. (Eds.). Psycholinguistic Series II. London: Elek.

Morton, J. (1979b) The Logogen Model and Orthographic Structure. In Frith, U. (Ed.) Cognitive Processes in Spelling. London: Academic Press.

Neisser, U. (1967) Cognitive Psychology. Englewood, Cliffs, New Jersey. Prentice-Hall.

Neisser, U. (1976) Cognition and Reality. San Francisco: W. H. Freeman and Company.

Ojemann, G. (1978) Organization of short-term verbal memory in language areas of human cortex: evidence from electrical stimulation. Brain and Language 5, 331-340.

Osgood, C. E. (Ed.) (1963) Approaches to the Study of Aphasia. Urbana: University of Illinois Press.

Pavio, A. (1971) Imagery and Verbal Processes. Holt, Rinehart, and Winston, New York.

Peterson, L. R., and Peterson, M. J. (1959) Short-term retention of individual verbal items. Journal of Experimental Psychology 58, 193-198.

Pirozzolo, F., and Rayner, K. (1977) Hemispheric specialization in reading and word recognition. Brain and Language 4, 248-261.

Premack, D. (1976) Intelligence in Ape and Man. Hillsdale: Lawrence Erlbaum Associates.

Prigitano, G. (1978) The Wechsler Memory Scale: A Critical Review. *Journal of Clinical Psychology* 34, 816-831.

Roemer, R. A., and Teyler, T. J. (1977) Auditory evoked potential asymmetries related to word meaning. In Desmedt, J. (Ed.) Language and Hemispheric Specialization in Man: Cerebral Event Related Potentials. Basel: S. Karger.

Rosch, E. (1973) On the internal structure of perceptual and semantic categories. In Moore, T. M. (Ed.) Cognitive Development and the Acquisition of Language. New York: Academic Press.

Russell, W. R. (1971) The Traumatic Amnesias. Oxford: Oxford University Press.

Russell, E. W. (1975) A Multiple Scoring Method for Assessment of Complex Memory Functions. Journal of Consulting and Clinical Psychology 43, 800-809.

Saffran, E. M., and Marin, O. S. M. (1975) Immediate memory for word lists and sentences in a patient with deficient auditory short-term memory. Brain and Language 2, 420-433.

Samuels, I., Butters, N., Goodglass, H., and Brody, B. (1971) A comparison of subcortical and cortical damage on short-term visual and auditory memory. Neuropsychologia 9, 293-300.

Seamon, J. G., and Gazzaniga, M. S. (1973) Coding strategies and cerebral laterality effects. Cognitive Psychology 5, 249-256.

Shallice, T., and Warrington, E. (1977) Auditory-verbal short-term memory and conduction aphasia. Brain and Language 4, 479-491.

Shiffrin, R. M., and Schneider, W. (1977) Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review 84, 127-190.

Smith, E. E., Shoben, E. J., and Rips, L. J. (1974) Structure and process in semantic memory: a featural model for semantic decision. Psychological Review 81, 214-241.

Talland, G. A. (1965) Deranged Memory: a psychonomic study of the amnesic syndrome. New York: Academic Press.

Tucker, D. M., Roth, R. S., Arneson B. A., and Buckingham, V. (1977) Right hemisphere activation during stress. Neuropsychologia 15, 697-700.

Tulving, E. (1972) Episodic and Semantic Memory. In Tulving, E. and Donaldson, W. Organizaton of Memory. New York: Academic Press.

Tulving, E. (1979) Memory Research: What Kind of Progress? In Nilsson, L. (Ed.) Perspectives on Memory Research: Essays in Honor of Uppsala University's 500th Anniversary. Hillsdale: Lawrence Erlbaum Associates. 19-34.

Underwood, B. J., and Freund, J. S. (1968) Effects of Temporal Separation on Two Tasks of Proactive Inhibition. Journal of Experimental Psychology 78, 50-54.

Walsh, K. W. (1978) Neuropsychology: A Clinical Approach. New York: Churchill Livingstone.

Warrington, E. K., and Shallice, T. (1969) The selective impairment of auditory-verbal short-term memory. Brain 92, 885-896.

Warrington, E. K. (1974) Deficient Recognition Memory in Organic Amnesia. Cortex 10, 289-291.

Warrington, E. K. (1975) The Selective Impairment of Semantic Memory. Quarterly Journal of Experimental Psychology 27, 635-657.

Warrington, E. K., Logue, V., and Pratt, R. T. C. (1971) The anatomical localization of selective impairment of auditory verbal short-term memory. Neuropsychologia 9, 377-387.

Waugh, N., and Norman, D. A. (1965) Primary Memory. Psychological Review 72, 89-104.

Whitty, C. M. W., and Zangwill, O. L., (Eds). Amnesia. London: Butterworths and Co., Ltd.

Wickelgren, W. A. (1979) Chunking and consoldiation: A theoretical synthesis of semantic networks, configuring in conditioning, S-R versus cognitive learning, normal forgetting, the Amnesic Syndrome, and the Hipprocampal arousal system. Psychological Review 86, 44-60.

Wickens, D. D. (1970) Encoding categories of words: an empirical approach to meaning. Psychological Review 77, 1-15.

Wood, C. C. (1977) Average evoked potentials and phonetic processing in speech perception. In Desmedt, J. (Ed.), Language and Hemispheric Specialization in Man: Cerebral Event Related Potentials. Basel: S. Karger.

Zaidel, E. (1976) Auditory vocabulary of the right hemisphere following brain bisection or hemidecortication. Cortex 12, 191-211.

Zaidel, E. (1978) Auditory language comprehension in the right hemisphere following cerebral comissuratomy and hemispherectony: a comparison with child language and aphasia. In Caramazza, A. and Zurif, E. (Eds.), The Acquisition and Breakdown of Language: Parallels and Divergencies. Baltimore: John Hopkins University Press.

DATE
LMED
8/1